2016 STATE OF GEOINT REPORT

USGIF
United States Geospatial Intelligence Foundation
Build the Community | Advance the Tradecraft | Accelerate Innovation

Acknowledgments

The United States Geospatial Intelligence Foundation (USGIF) would like to thank the GEOINT Community representatives from government, academia, and industry who participated in the second annual State of GEOINT report. The multi-day discussions with more than 50 participants from varying agencies, industries, backgrounds, and experience identified a variety of GEOINT Community trends and challenges. We sincerely appreciate participants dedicating time away from the office to help uncover and articulate key themes in the articles that appear in the following pages. USGIF would also like to thank staff that made the State of GEOINT exchanges and publication possible. Justin Franz, volunteer engagement manager, helped organize and facilitate the State of GEOINT Content Exchange. Anna Kimmel, director of events, organized a USGIF Thinker's Dinner to discuss the report's themes. Kristin Quinn, editorial director; Lindsay Mitchell, marketing & communications assistant; and Jordan N. Fuhr, vice president of strategic communications & marketing, edited and managed the publication's production and distribution.

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2016 State of GEOINT Report

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Foreword

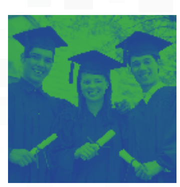
Established in 2004 as a 501(c)(3) nonprofit, non-lobbying educational foundation, the United States Geospatial Intelligence Foundation (USGIF) has provided leadership to the GEOINT discipline via the three pillars that define the Foundation's goals: Build the Community | Advance the Tradecraft | Accelerate Innovation.

USGIF fosters the once emerging and now rapidly broadening discipline of geospatial intelligence as well as supports the professionalization of the GEOINT workforce through myriad events and activities. Whether at networking events such as GEOINTeraction Tuesdays, professional development opportunities hosted by the Young Professionals Group, educational activities such as hands-on training sessions, or large-scale community-wide events like the annual GEOINT Symposium, USGIF is recognized as the convening authority for the GEOINT Community. This is evidenced in part by the breadth of military, government, industry, and academic participation across all Foundation activities—to include this second annual State of GEOINT Report.

Ongoing anecdotal feedback regarding the 2015 State of GEOINT Report convinced us the report should indeed be an annual endeavor. These reports, crafted by and for USGIF Members and the GEOINT Community, offer a platform to examine current topics of interest and to encourage discussion and forward thinking surrounding new ideas and concepts. With the advent of the GEOINT Revolution, there has never been a more important time to rally the intellectual energy of the extended GEOINT Community and provide thought leadership regarding this discipline.

This year's report explores multiple topics of current interest, none of which should surprise even a novice GEOINT practitioner. I do, however, believe the report offers thought provoking ideas for even the most experienced GEOINTers. Our strong desire is that the State of GEOINT Reports will annually create a platform for discovery and learning.

We appreciate the efforts of our Member volunteers for their hard work and diligence in support of this publication. Based on the inaugural report's success, I'm confident this report will continue to add value and stimulate rich discussions about the current and future state of GEOINT.



Keith J. Masback, CEO, USGIF

THE STATE OF GEOINT 2016
GEOINT as a SERVICE
Democratization of GEOINT DATA
Machine-Learning aiding analysts
Ubiquity of DATA
SYNTHESIS
Commercial
Commercial capabilities outstripping USG
Volunteered Geographic Information
Government
Crowd-sourcing
GLOBAL PRACTICE
TRAINING How to use technology as a tool
EDUCATION What it means to analyze
Evolution of GEOINT
CULTURE of tradecraft
Open Source
Small Sats
GEOINT University
#drought
#hunger
#flu
Human Geography
3-D Mapping Visualization
#trends
#politics
#marketplace
Graphic Processing Units
USGIF
Visioneering
OGSYSTEMS

Introduction

Each year USGIF assembles a wide variety of GEOINT subject matter experts, practitioners, businesspersons, and thought leaders to create an annual State of GEOINT report. Building on well-known acquisition and procurement concerns, the 2016 document includes myriad views from more than 50 contributing authors representing almost 40 organizations.

To create the 2016 State of GEOINT report, USGIF started by polling its membership and accredited collegiate programs to ask which topics were of interest for possible inclusion in this year's publication. An extensive list of topics was generated from the informal survey. On Oct. 6, 2015, USGIF hosted an open, in-person, facilitated gathering where many of the pre-selected topics were debated and additional topics were introduced into the conversation. Teams of authors self-formed and the writing process began in earnest. Each article began as a short summary and had a minimum of three contributors—our nod to peer review.

A strong addition to this year's publication is the graphic facilitation provided by the OGSystems visioneering team. The visoneers not only created an accompanying graphic on page 4 that incorporates the main themes found in each of the following articles, but also provided graphic facilitation during a USGIF Thinker's Dinner in December. Thought leaders convened at the Thinker's Dinner to discuss GEOINT community trends and provide additional input to this publication.

This report's final selections highlight a number of pressing issues for our global GEOINT Community: the loud trumpeting of the arrival of small satellites as a recognized, disruptive, and viable collection platform; the proliferation of open-source data; the direct and visible impact of volunteered geographic information; the need to revamp training to match the use of new and open sources; and the immediate and ever-pressing need for improved government procurement. The demand for GEOINT training and education is also a strong theme woven throughout this report.

Additionally, there is universal acknowledgement among this year's State of GEOINT authors that GEOINT as a discipline has grown far beyond the banks of the Potomac and is now a global phenomenon. This understanding is also reflected in other USGIF activities. The theme for the upcoming GEOINT 2016 Symposium is "The GEOINT Revolution," which explores how commercial and non-IC/DoD communities are furthering the application of our discipline. Furthermore, USGIF is fulfilling one of its core missions as a 501(c)(3) educational nonprofit by launching a professional GEOINT certification for both traditional and non-traditional global GEOINT workforce development.

USGIF strives to provide publications of value to the GEOINT Community. Researchers, analysts, government officials, and business development professionals will all learn from this eclectic, hard-hitting set of articles and gain a better understanding of the tradecraft. Each article is designed to provide insight and provoke reaction. If you have a comment on an article, an idea for a future State of GEOINT topic, or are simply interested in participating in State of GEOINT activities, please email StateofGEOINT@usgif.org.

I would like to personally thank all authors and colleagues for their contributions, as well as thank their respective organizational leaders for allowing them the time to participate. I continue to marvel at the breadth and depth of our community and am humbled to help bring to life the many disparate views of GEOINT students, practitioners, technologists, managers, and leaders. My mantra and experience remains constant: GEOINT is a team sport. We must share and embrace our different opinions and experiences. Together, we will benefit from these differences, as they will lead us to many opportunities for personal and organizational growth.

Darryl Murdock
Vice President of Professional Development, USGIF

About the Artist

OGSystems Visioneering uses drawing, Appreciative Inquiry, and guided graphic facilitation techniques to lead teams through a variety of meetings, discussions, and offsites. The Visioneers guided USGIF leadership in translating big ideas from the 2016 State of GEOINT Report into the mural on page 4. The OGSystems Visioneering Team based in Chantilly, Va., leverages industry leading practices and its own methodologies to enable teams, leaders, and stakeholders to achieve breakthrough understanding and increase engagement, impact, and concept retention. To learn more, please visit the OGSystems Visioneering website: https://www.ogsystems.com/visioneering.aspx

2016 STATE OF GEOINT REPORT

Immersive GEOINT: Surrounding Analysts With Information

Big Data. Human Geography. GPS-enabled…everything. These are the buzzwords and marks of the GEOINT world of 2015. In many ways, what once was a pair of disciplines that matched our location to a place on the globe (mapping) and identified objects of interest on a film print (imaging) has become the source of a continuous wash of context captured and graphically enhanced life information. GEOINT affects our understanding of every aspect of our lives and informs us how we interact with and relate to places in the world. Evolving technologies for information presentation, manipulation, transmission, and access constantly influence our way of responding to the world.

The full impact of the sweeping changes that our new technologies enable has barely begun to be felt. From the perspective of a GEOINT professional, every aspect of how we ingest, comprehend, and forward information will change in the next 10 years. For an analyst—someone responsible for bringing meaning to the data available on events in our world—the professional environment within the U.S. government will bear little resemblance to that of the IC ITE workstation-bound staffer at the National Geospatial-Intelligence Agency (NGA) today. For those more directly interacting with the world (i.e. business analysts, military and intelligence operators, emergency responders, peacekeepers, environmentalists, etc.) there will be an even more radical transformation in their understanding and ability to react. This article explores the possible analytic and field operations environment of 2025.

The Future Analyst Worksphere—GEOINT Beyond the Uncanny Valley

For the last 20 years, the vanguard of application for data manipulation and display has been in the entertainment sector. HD display, 3D color projection, wireless input/output devices, and chat functionality initially evolved to improve user experience for video games and movie theaters. While forward-thinking members of the intelligence and geospatial communities were early adopters of these technologies, practically all of the investment and innovation came from other sources.

Those who have for a long time worked in the U.S. government-led GEOINT Community recognize the gap in accessible resources for data gathering and manipulation imposed by institutional policies. GEOINT professionals at NGA leave most of their smart information gadgets (GPS-and/or Wi-Fi-enabled smartphones, cameras, tablets, or other mobile computing devices) in the parking lot on their way into the office. This sacrifice is considered the price for security needed to access the special capabilities made available by intelligence sources. The question is, in the world of 2025, will the additional insight gained by classified intelligence sources be worth the sacrifice of timeliness, technology, and openly available content lost at the door?

As youth who have never experienced a day without Twitter, Instagram, Snapchat, or Pinterest—who conduct "research" by opening Wikipedia and linking to source documentation and monitor their every activity with Fitbit and Apple Watch—enter the GEOINT workspace, they are radically underwhelmed by available tools, techniques, and processes. For example, newsworthy events are often posted, discussed, and dissected on Twitter before they are even detected in more traditional ways. Thus far, attempts to duplicate open capabilities inside the secure world suffer from the economies of scale the open cloud provides. To fully enable our workforce, true access to all information portals will need to be embraced. If this occurs, then the analyst of 2025 would experience a very different spectrum of activities for information gathering and synthesis.

HyperSight: Fully Integrated Virtual Reality (VR)

With the full commercial release of products such as Oculus Rift and Project Morpheus on the horizon, gamers are taking the lead on technical problem solving and appropriate or optimized user control efforts. Applications for Xbox Kinect, PlayStation 4, and other platforms are being tested for seamlessness, tendencies to cause motion sickness, ease of accommodation (time to get used to the environment), and comfort of user hardware. The challenge for the GEOINT Community will mostly be in designing interfaces to match available sources of data and creating information that can effectively integrate with these tools. The community will also need a fundamental understanding of spatial cognitive capabilities to develop guidelines for effective information communication in the paradigm of virtual and augmented realities, including when to present what information, how much information to present, and how to synthesize the information to best reveal hidden patterns.

For the gaming community, the most interesting challenges involve how to combine immersion in the game with overlays of necessary information to provide status without ruining the illusion. In a very real sense, this issue will be ours as well (Charara, 2015)[1]. At present, contextual data (e.g. latitude/longitude, spectrum, time of day, etc.) is provided on the side of a screen, but in a properly designed VR environment the display surrounds the user. Two potential solutions to this problem are: 1) take a cue from the augmented reality community and providing hypertext style headers on or near objects of interest that can be queried by gesture; or 2) make part of the virtual display a panel that can be referenced to find data. Research indicates increased immersion can put additional demands on cognition. Perhaps symbols based on messaging or "glyphs" could be a way to intuitively convey complex data without overly taxing the user.

To improve analyst effectiveness in a VR environment, the boundary between remotely collected data and in situ context information must be further blurred. Today, Google Earth and classified data providers alike drape imagery collected from high altitude or space over 3D models provided by LiDAR or other devices to enable moderately accurate "fly-through" of urban environments. In a full VR environment, improved resolution should be a major goal. Companies such as Uncorporea, Pictometry, and VRICON make the integration process more seamless with applications in our community. Advanced ray-tracing at the pixel level of items in the scene allow for a full blending of real and non-real objects in a scene in motion. Combining this approach with community-developed phenomenological, dynamic, and rendering tools (e.g. DIRSIG, STK, and SolidWorks) would allow for effective synthesis of real information at the level of physics.

A challenge in creating a truly virtual workspace is the single-user nature of the display tools (i.e. headsets) involved. Microsoft is testing a commercial augmented reality product called HoloLens, and researcher Jaron Lanier is developing an application called Comradre that will allow multiple users to see and interact with a projected object—each from his or her own perspective. This will enable analytic collaboration within the VR realm (Knight, 2015)[2].

To further simplify the optical display element of a virtual analytic office, a goal of the information display community is to move toward more direct interaction with the optic nerve. Projection systems (even contained inside of contact lenses) and better motion detection systems (capturing motion at the eye rather than head level) will improve the intuitive feel of virtual input imagery and data.

Multisense Feedback (Haptics/Audio)

To improve the efficiency and intuitive capability of our future analysts, the experience of information should move beyond the visual and take advantage where possible of our other senses. Computer devices already exist for interaction with information provided as sound, movement, pressure, and temperature, and there are efforts to enable synthetic odors as well.

The main reason for incorporating these multi-sensing constructs into an analyst's workspace is to enable true and effective multitasking. Humans in the natural environment respond simultaneously from inputs to all senses without being forced to focus conscious attention on every stimulus. A good example is the experience of driving a car. Unless you are a new student driver, the process of accelerating, changing lanes, stopping, etc. is one of integrated touch/sight/sound activity all done in harmony at a nearly autonomic level. You don't think, "I'm going to let up on the gas now, while looking each direction and listening for car horns so that I can move over one lane." Your body just executes the maneuver sequence. In a properly configured environment designed to support real-time decision-making and activity-based intelligence, the stimulus to examine a different viewing geometry, back away from the scene, focus on a change detected remotely or by in situ sensors on scene, etc. could be given in cues of sound, vibration, or temperature changes on the immersed analyst's extremities. After a suitable training period, similar to that involved in learning to drive, the analyst would be able to intuitively take reflex actions to manipulate elements of the data stream while maintaining focus on its larger meaning.

At a minimum, next generation data manipulation systems should make thorough use of temperature, pressure, vibration, and stereo sound and imaging as part of the user input/output/query experience.

Artificial Synesthesia

As more experience is gained in the multisensory environment, analysts could take cues from those individuals who are blessed/cursed with the sensory crossover condition called synesthesia. Individuals with this condition experience senses in a coupled manner, for example "hearing" colors, or seeing a color correlation to a number. A visual/numeric

1. Charara, S. (2015, March 24). *The problems facing VR game designers and how to fix them*. Retrieved October 20, 2015, from Wareable: http://www.wareable.com/vr/vr-game-design-problems-fix-eve-valkyrie-ccp-668
2. Knight, W. (2015, October 12). *Microsoft Researchers Are Working on Multi-Person Virtual Reality*. Retrieved October 23, 2015, from MIT Technology Review: http://www.technologyreview.com/news/542341/microsoft-researchers-are-working-on-multi-person-virtual-reality/

synesthetic can, on inspection, see the four nines on a full page of single-spaced typed sixes, since they appear to this individual to have a different color. If an analyst needed a better sense of activity in a monitored scene, changes could be linked to auditory or pressure cues that would elicit rapid response, reducing the required processing time for critical decisions. The optimal analyst use of such cueing systems would have to be user-orchestrated and specific. Whereas one user might use a "ping" auditory cue as a warning, another might want a vibration cue for the same purpose.

The development goals for an immersive analytic environment tuned to the U.S. government workforce should be threefold:

1. **Maximize the leverage of tool and application development done for other purposes.** There are two reasons for this. First, our user community will exploit these tools outside of the workplace for their own purposes, and the more seamless the technology interface, the more "training" for use of our resources is done by happenstance during off hours. Second, limiting our internal development to those parts of a problem unique to GEOINT professionals, such as defining targeting points for military munitions or fire-response teams, maximizes our ability to invest in the best capability for these applications. This is the same strategy for ground as NGA Director Robert Cardillo is advocating for collection: leave the work that can be done by others to be done by them.

2. **Ensure the integration of data and information from our specialized sources is to the greatest extent possible seamless with that provided by outside sources.** Right now, cross-referencing of special or classified information involves separately referencing multiple sources, often on different systems. In a VR environment, most of the benefits of the system would be lost under such circumstances. This is the cyber equivalent of having to open a window to check the weather.

3. **Actively support and promote advancement of relevant standards for open-source device integration.** The reason people still type data on a QWERTY keyboard is not because this device is optimized for input/output—quite the contrary (Stamp, 2013).[3] The device was originally a response to a combination of mechanical limitations and attempts to align some functionality with Morse code transcription to text. The sooner optimal controllers for I/O are defined, the more likely universal adoption will make these devices commonplace outside of our professional environment (and thus natural to employ).

Taking advantage of resources in data manipulation will allow the analyst of 2025 to be a more effective participant in the GEOINT world as well as make the job more dynamic and interesting to perform.

Working in the Augmented Geosphere—Metareal Operations

The world of augmented reality (AR) is already felt in entertainment and gaming. According to Wikipedia, AR is a live direct or indirect view of a physical, real-world environment whose elements are augmented (or supplemented) by computer-generated sensory input such as sound, video, graphics, or GPS data. It is related to a more general concept called mediated reality, in which a view of reality is modified (possibly even diminished) by a computer. AR technology functions by enhancing one's current perception of reality.[4]

As more devices are put on the market designed around experiencing data, rather than just viewing it, the tools to support such activities will become more rugged, lighter, and less expensive. At the same time, as human-machine interface technology improves, various human enhancements will be possible where appropriate (think Iron Man, or the walkabout worksuit devices in Avatar). As the blend of location-driven reality and cyber virtual augmentation continues, the operator of 2025 will function in an environment that doesn't exactly fall into either category.

First Steps: Augmentation of the Visual

"Perception is reality." - Lee Atwater

Sure, Atwater was a political strategist talking about election campaigns, but let's think about the above statement for a minute. The perception of a GEOINT problem on paper or a screen is innately limited. Analysts are never "there" or see the problem in physical/sensory context.

An operator, though situationally aware with immediate sensory context, is still limited. They may be starved for strategic knowledge, an often-necessary component for the proper analysis of the current issue.

Perhaps the future of GEOINT is to minimize the strategic and tactical gap as accurately and quickly as possible. The means to that end is likely an immersive environment applied over an array of personalities and skill sets to derive proactive and validated outcomes.

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3. Stamp, J. (2013, May 3). *Fact of Fiction? The Legend of the QWERTY Keyboard.* Retrieved October 21, 2015, from Fact of Fiction? The Legend of the QWERTY Keyboard: http://www.smithsonianmag.com/arts-culture/fact-of-fiction-the-legend-of-the-qwerty-keyboard-49863249/?no-ist

4. Multiple. (2015, October 19). *Augmented reality.* Retrieved October 20, 2015, from Wikipedia: https://en.wikipedia.org/wiki/Augmented_reality

How do we really make perception reality, and do so in real-time (or perhaps even ahead of time)? Possibly, we begin by melding the training scenario process with the actual operation. Mission dress rehearsal is a critical aspect of any well-executed operation, but is often hard to credibly execute. Preparing a VR scenario, then adjusting to add reality to the blend might be a step-wise solution.

In "Star Trek: The Next Generation," the creative vision and implications of the "holodeck" were explored in depth. In addition to the obvious entertainment value of complete contextual immersion and the ability to interact with scene components, the facility was quite often exploited for scenario development and tactical rehearsal for planned "away team" activities. As the projection and augmentation technologies mature, one can easily posit use of such a facility for dry runs to support special operations missions, or process-flow rehearsal for firefighters to plan ingress/egress and other activities. Moving from planning to operations, including the same hypertext iconography on augmented reality heads up displays (HUDs) will help improve operator familiarity and ease-of-use for the tools provided.

In addition to the ability to look from more than one team member's perspective, and geographic feature ID, additional capabilities for a properly designed HUD could include such features as:

1. Projection from floor plans into the interior of spaces to be entered
2. Overlays of areas where operators are exposed to snipers or guard towers
3. Vehicle ID information
4. Friend or foe (red/blue force) identifiers
5. Logistics information (e.g. battery, fuel or military munitions reserves, availability of fire-retardant chemicals, proximity of medical care, etc.)

The goal of early and constant integration of these information inputs is to enable a reflex-like response on the part of the users/operators. The more natural this enhanced information profile is, the better chance individuals in harm's way have of effectively responding to threats and opportunities.

Looking at the government-industry implementation strategy, it is important to note the Open Geospatial Consortium (OGC). Sensor Web Enablement (SWE) architecture is designed to support the seamless integration of space-based, airborne, mobile, in situ, and terrestrial remote sensors with standard OGC-enabled geospatial data. In a world of massively distributed constellations of heterogeneous sensors brought in to augment both in situ/embedded operators and remote analysts, the instant availability of the latest and greatest location-aware, geospatially-enabled sensor data radically and permanently changes the experience of each type of information. But the experience can go further still.

Direct Body Augmentation: Overtly Affecting Activity Performance

As the gaming industry leads the way in development of capabilities which will support the future analyst, the professional sports world is the vanguard in tools and techniques for advanced applications of operations augmentation gear. According to *Fortune*, the NFL cut a deal with Zebra Inc. to put motion capture RFIDs in practically every piece of gear involved in play. By the end of next year, every player's arms, legs, helmets, chest pads, and even the ball will be monitored for dynamics at all times. Part of this is to improve television; the rest is to study, monitor, and impact player performance (Vanian, 2015).[5] All of this has direct application to operators performing difficult tasks under dangerous and time-critical conditions.

In the future, where the bandwidth is available and the data formats stabilize, all operators should be equipped with displays and monitoring technology to show them red/blue force positions/status/health, communication availability, and so on. To the extent possible, the sensors and displays should be fully integrated with his or her other gear, both for ease-of-use and to avoid hindering physical flexibility. Control of this new gear could come in surprising ways.

Research is ongoing in several locations (e.g. EMOTIV, Chaotic Moon) on direct read external neural interfaces. This technology uses a portable version of an electroencephalogram (EEG), and with training allows a user to directly send control actions to remote objects. Combined with gestures already in use for tactical control of special operations troops, robots and other such devices could be made to surveil dangerous locations, defuse or detonate bombs, search for survivors, and more while the operator applies much of his or her attention to other matters.

Beyond improved sensory awareness, related research is working to enable physical enhancement. For example, DARPA is researching exoskeletal suits that allow a soldier to carry significantly more gear without feeling the strain. U.S. Special Operations Command is working toward an integrated soldier protection, monitoring, and support uniform under its Tactical Assault Light Operator Suit (TALOS) program. To a great degree, TALOS is Iron Man without the flight or directed energy weapon capabilities. Proper integration of the multisense systems discussed above will be critical to ensure the operator's situational awareness and flexibility.

5. Vanian, J. (2015, September 11). Inside the NFL's big data play. Retrieved October 21, 2015, from Fortune: http://fortune.com/2015/09/11/nfl-big-data-stats/

Conclusion: Back from the Future

A key challenge in enabling both the future analyst and operator is overcoming bandwidth limitations to make information available in real time. Either the user community will have to be exceptionally smart in defining the data formats and transmission protocols to match limited connectivity, or development of better and more secure communications will have to be a principal investment goal for the immediate future. It's likely a mix of both strategies has the best chance of success.

One positive step in effectively integrating immersive GEOINT comes from the AR community. Not many outsiders are aware the Augmented Reality Markup Language (ARML) programming standard began in the AR community, but consciously chose to align with the OGC in order to harmonize with the world of geospatial standards. As a result, ARML is now an OGC standard. This means there is a natural bridge between ARML and OGC standards NGA has already adopted as its baseline interoperability specification.

In contemplating the evolving GEOINT workforce, it is important to remember it is our young children who will perform these new tasks. What is still the stuff of science fiction films for those of us currently in mid-career will be the grade-school baseline for upcoming professionals. They will have never lived a day without Wi-Fi-enabled devices, never had a new movie or game come out without HD, 3D, or both, and never experience the inability to get questions answered immediately via voice or text query. Their clothing and jewelry will be "smart"—monitoring their functions and suggesting options to improve their life and/or lifestyle. In all likelihood their identities will be secure, due to systemic biometric monitoring and control. Our responsibility today is to design and define the best possible tools to enable current and future workers to effectively utilize GEOINT information. ■

Deep Learning: An Industry & Academia Viewpoint

The New Analysis Team Member

Geospatial intelligence provides insight into human activity and as such requires the analysis team to first forage for data and then to make sense of that data, or "sensemake". The foraging effort is time consuming, focused on seeking, searching and filtering, and extracting information. Sensemaking is the ability to understand and explain an ambiguous situation, create situational awareness, and understand conditions with high complexity or uncertainty in order to make decisions that achieve a relative advantage. Sensemaking is "a motivated, continuous effort to understand connections (which can be among people, places, and events) in order to anticipate their trajectories and act effectively".[1] As the volume, variety, velocity, and concerns over veracity of data increase, foraging efforts become overwhelming, robbing time from the sensemaking process and negatively impacting intelligence decision cycles.

The U.S. Intelligence Community (IC) has been confronted at times with too much data, and at other times sparse data. This is especially important given the explosion of unstructured data in the form of web content, social media, and video. At the same time, the intelligence landscape has become increasingly complex. Rather than simply requesting observations and confirmations, leaders seek comprehensive adversary analysis to include behavior and intent. In response, the IC uses various technologies to assist in the acquisition and interpretation of data. The objective is to reduce data foraging time to allow analysts to do what humans do best—make sense of complex situations and provide a decision advantage to leaders.

Deep Learning (DL) holds great promise in addressing the data foraging challenge. With the general availability of massively parallel computing, deep learning computers will become a defacto "member" of the analysis team by successfully solving tasks requiring repetitive recognition, signature detection, and event alerting. The computer can explore new and varied data, narrow the set of items collected, exploit items in the narrowed set, and trade one against another—all of this carried out under deadline or data overload constraints. Furthermore, deep learning can elicit representations and relationships that may not be readily apparent. In this way, the computer becomes an assistant or sentry that forages for information at speeds

1. Klein, G., Moon, B., and Hoffman, R.F. 2006. Making Sense of Sensemaking. IEEE Intelligent Systems, 21(4), 70-73.

heretofore not available in the industry. Humans can then focus on the higher-level critical geospatial reasoning required to address complex problems.

Deep Learning: Ready to Report to Work

DL is a branch of Machine Learning (ML) where computers are trained to perform tasks by learning from experience. Suppose you have thousands of images of animals and want to tag each image with species. A model is proposed that attempts to predict the species based on features derived from the pixel values. The parameters of the model are randomly initialized meaning the model randomly predicts the species with poor average accuracy. The parameters can be iteratively trained by repeatedly passing the training images into the model and making small adjustments to reduce the error between the predictions and the known species. The resulting trained model can be used to accurately associate previously unseen images with species.

The benefits of the ML approach include:

- The ability to learn the most important, and often subtle, features in raw data, subtleties which are often not apparent to humans
- Robustness to variations (noise) in real-world data that can confuse simpler, hand-crafted approaches
- The ability to be retrained at speeds that exceed human capability
- The ability to adapt models over time and in response to new data

DL is used across a wide range of industries to make sense of messy, raw data and provide insight for decision-makers. For example, DL is used in many commercial applications and by winning data science teams in a variety ways, including:

- Object detection, image classification, and segmentation (Image Net)
- Text recognition in imagery (Google Street View house numbers)
- Pedestrian Detection and Human Action Recognition (INRIA, Hollywood II)
- Photogrammetry and shadow detection (UCF, CMU, UIUC data sets, Stanford bgd, SiftFlow, Barcelona, MIT-67, NYU RGB-D)
- Activity-based Intelligence (Kaggle Taxi destination prediction)

Over the past few years, use of DL has transformed machine perception applications. In image classification, DL-based systems achieve 95 percent accuracy, which depending upon the data can exceed human performance. Similarly, use of DL has enabled a step change in machine understanding of audio data and natural language text, enabling new applications in real-time transcription and translation of spoken language.

Leading web-scale technology companies are investing heavily in acquiring and developing DL expertise. In the last three years, Google, Facebook, Microsoft, and Baidu have hired leading academic pioneers to develop DL applications. These applications have been deployed in production systems such as Google's voice recognition and FaceBook's face recognition. These companies drive cutting-edge DL research and deploy new applications on a continuous basis, including offering "Machine Learning as a Service" (Amazon).

In DL, the computational models are referred to as Artificial Neural Networks (ANNs). ANNs are biologically inspired and consist of a hierarchical network of simple computational units called neurons. The "deep" in DL stems from the fact that these ANNs have many stacked layers, each with many neurons. Each neuron performs a simple operation and feeds the results to the next tier of neurons. A deep ANN can learn a hierarchy of data features that correspond to a hierarchy of real-world concepts. Arranged in complex topologies, these networks compute very complex functions. In fact, given a sufficient number of these artificial neurons and a large amount of appropriate training data, ANNs can learn almost any function mapping raw data to a decision.[2]

DL has been criticized as a simple rebranding of neural networks. Although the mathematics of today is not drastically different than that proposed for early neural networks, three critical enablers have emerged in the past decade. Most important is the unprecedented volume of annotated data available online and from ubiquitous sensors that can be used for training ANNs. Secondly, the emergence and use of highly parallel GPU-based computing clusters has greatly reduced ANN processing timelines to weeks, days, or even hours. Finally, new algorithmic techniques that prevent model over-fitting and augment standard training have made DL faster and more reliable.[3, 4]

DL frameworks vary in accessibility and extensibility. Applications and tools are available in a variety of popular software frameworks from leading academic and commercial organizations. For example, Torch, Theano, OverFeat, and Caffe are available on GitHub. These frameworks provide computationally efficient implementations of the common building blocks for designing, training, and deploying ANNs. Furthermore, they typically allow training using parallel computation on GPUs. For example, the

2. https://en.wikipedia.org/wiki/Universal_approximation_theorem
3. Dahl, George E., Tara N. Sainath, and Geoffrey E. Hinton. "Improving Deep Neural Networks for LVCSR Using Rectified Linear Units And Dropout." Acoustics, Speech and Signal Processing (ICASSP), 2013 IEEE International Conference on. IEEE, 2013.
4. Bengio, Yoshua, et al. "Greedy Layer-Wise Training of Deep Networks." Advances in Neural Information Processing Systems 19 (2007): 153.

NVIDIA DIGITS framework provides a code-free interface to design and train ANNs for image classification. At the other end of the spectrum, Google's newly released TensorFlow framework provides almost unbounded expressiveness for building DL applications.

One common concern when considering how to apply DL to a new problem set is a lack of available training data, but this is not always a barrier to the adoption of DL. Common practice is to train an ANN on one set of training data and then transfer the general knowledge encoded in that model for new related context. This technique is known as "transfer learning."

Similarly, there is promising research and growing interest in methods for unsupervised training of ANNs. Using unlabeled and unstructured data, the network discovers the structure and patterns hidden in this data and uses that knowledge for tasks such as data visualization, clustering, and similarity-based search.

So What? Deep Learning is More Than Collection and Analysis!

Humans are at the pinnacle of the cognitive hierarchy. Use of DL relieves humans from performing high-volume, repetitive, lower-order cognitive tasks, thereby yielding the greatest productivity. Applied to geospatial intelligence analysis and collection, deep learning can quickly perform high-volume, fundamental tasks and support complex analysis such as detection, classification, clustering, observation, and anomaly recognition. Thus, the greatest productivity results not from a strict division of labor, but rather from human-computer interaction in which the strength of each is optimally employed through a collaborative interaction.

Similar to any other interactions with technology, trust is necessary and must be built. First, DL uses data from verified sources to understand the nature and context of the problem. Second, these systems improve over time as they learn more about a particular area of knowledge. Unfortunately, they run into limitations in their ability to adjust at the boundaries of their knowledge domains, but this is where the analyst comes into play. Third, humans will need to exert supervisory control so they are "on-the-loop," as opposed to "in-the-loop." As part of this, humans will need to set the context for the system.

Application Areas for Deep Learning

Applications of DL include crises response management, unmanned vehicle operations, air traffic control, and industrial process control. For example, geospatial analysis teams are confronted with an enormous unmanned aerial vehicle data volume. A DL system could reduce this data without loss of salient details, providing alerts for pre-selected objects, maintaining tracks, monitoring activities, detecting structural changes, and identifying anomalies. Using a summarization process, full-motion video could be distilled to the most salient key frames for event detection in the context of the analytic problem.

Pattern of Life (POL) and similar analyses have become staples in understanding behavior ranging from provocative to normal, and in developing appropriate courses of action. Use of DL has the ability to identify objects and patterns and then differentiate expected normal behavior from anomalous unexpected behavior. In intelligence applications, computers would count cars in a parking lot to assess the number of people inside a building, determine the presence of ships, aircraft, or material at a military facility, or differentiate military training exercises from prepositioning troop movements in preparation for war.

Continued advancement in neural networks is rapidly improving the efficiency of these tasks, driving down false alarm rates and enabling automated inference of intent and understanding of activity. One can envision computer learning used to recognize spoofed sensor data, military deception or similar subterfuge occurring via misinformation and use of decoy data. Continued training of a deep learning system refines the collective human-machine intuition in spotting data that is "just not right" and ensuring false positive and false negative assessments are not derived from misinformation.

DL applications will extend from a focus on the data alone to incorporating analytic models. Humans have a monopoly on the cognitive capability to translate unstructured problems into structured frameworks, analytic models, and supporting hypotheses. There is an implied "cost function" in choosing appropriate models that trade off time to create a model and receive output against quality of the model's output. DL could reduce the time to develop and vet a model and increase the quality of a model by recognizing patterns within a model's structure, recalling similarly structured models, and identifying gaps in a model. Additionally, DL could continue to observe model structure and develop a "weighing" that when tipped far enough would assist the analyst team in updating its model for higher fidelity output. Use of DL may allow the analyst to "distill out" the important features of a task.

As DL is used to observe and learn analysts' behaviors, modeling approaches, and procedures, it could make observations that have been overlooked, recommend alternative approaches, and support continued evolution of the tradecraft. One major benefit will be the ability to retain knowledge and make it available for junior analysts. For example, analysts could personalize a DL model to include the questions they ask and the labels they apply. The potential would also exist to extend this capability across inter- and intra-organizational analyst teams thereby creating a greater intelligence capability than the sum of individual analytical cells. How this process is personalized at the analyst level will be a function of trust, tradecraft vernacular, and analyst experience.

What's Next?

In summary, DL has the potential to dramatically improve our ability to understand the world around us and to make sense of the information we collect. Much promise exists in the way industry and the community are driving analytics of all kinds towards actionable insight. As GPUs become more ubiquitous in analytic environments, DL capabilities will be available "out of the box." Tradecraft will be impacted, with DL augmenting, complementing, and assisting the human. Yet with all this promise, there are a number of challenges that must be met before the potential of our "newest analytic team member" can be fully realized:

1. Formulating problems for which enough data is available to make DL algorithms converge on an output. For example, we know how to apply DL for video but there's not enough labeled data to make it viable (unsupervised learning) except for Google/Facebook. In addition, machines may create new attributes the human would never create. Trying to fit these results to fixed schemas or ontologies is a fundamental challenge.
2. Trust is critical. For defensible assertions we must be able to trust machine results. There must be ways to validate what DL does without understanding the inner workings.
3. DL requires modern GPU hardware to achieve results. The current government procurement pace and lack of commercial software libraries complicate implementation.
4. Given the potential impact on tradecraft, a collaborative, cross-agency DL working model is needed for promulgating lessons learned and identifying workforce needs.
5. We must catch up with commercial industry, which is far ahead of the IC in adopting DL. Identifying DL projects in the commercial space that directly apply to IC problem sets and adopting them could dramatically accelerate IC capability.
6. Embracing the depth and breadth of transformative industry solutions at the agency, inter-agency, and tradecraft level as they relate to sensemaking and cognitive computing.

Ultimately, the IC will need to accelerate research aligned with baseline programs of record, ensuring how use of DL can satisfy documented program requirements in the long haul. Future problems will be more diverse and richer in data and metadata. We must look to the increasing sophistication of cognitive services such as DL to help us make sense of the situations and predict future outcomes. But with a future this bright, it's great to know the newest member of our analytic team is ready and able to help us take intelligence estimates to the next level. ■

Building Geospatial Analysis Capacity Through Training

A Brief History of GEOINT Training

Historically, a lack of access to geospatial content and technology created natural barriers to entry for the GEOINT profession. Members of this government-centered community frequently came from the established disciplines of imagery analysis, geography, and cartography, which had separate educational curricula, training pathways, and associated credentialing. Later, with the improvement and commercialization of GIS Science and Technology, including Geographic Information Systems (GIS), the geospatial analyst role was created.

Fast-forward a few years, and advances in sensors and technology have not only increased our ability to more precisely know the Earth, but also have resulted in the democratization of GEOINT. Everyone with a computer and an Internet connection is now able to quickly access recently collected, high-resolution imagery and conduct geospatial tasks using freely available online open-source tools. This capability was barely even imagined 50 years ago. Moreover, advances in multi-INT analysis are enabling successful integration of geospatial sources with other content in support of meaningful analysis given the true complexity of our world. Effectively anticipating this model and its effect on the U.S. government's ability to conduct GEOINT work, the National Geospatial-Intelligence Agency's (NGA) 2020 Analysis and Technology Plan describes the "integrated analytic environment," which "will enable analysts to discover, access, organize, display, exploit, analyze, and expose data and intelligence within a single, unified framework."

Within the context of this rapid innovation, three challenges have emerged for the GEOINT Community. First, there is the subtle transition of GEOINT education from geospatial concepts and principles to training emphasizing proficiency in technology or "buttonology" over critical geospatial thinking. While the ability to effectively use these new tools might be necessary, it is not clear whether this type of technical proficiency is sufficient to fully enable the effective and responsible practice of GEOINT, or if its use even requires geospatial knowledge. The second challenge is the increased accessibility of geospatial sources and methods to practitioners outside the traditional GEOINT domain. The availability of content coupled with associated ease of use and decreased cost of geospatial tools has resulted in a democratization of GEOINT, prompting the geospatial community to question whether GEOINT will remain a separate professional discipline, or if it has evolved to just another "INT" available to the analyst. Finally, recent emphasis by the Intelligence Community on multi-INT analysis has increased interest in and use of geospatial content by other intelligence professionals who may or may not have GEOINT training. As the GEOINT Community has professed for years, location matters—everything can be described by location data within a spatial context. Now that the larger community has heard our call and is actively incorporating geospatial sources, methods, and tools into its own analytic workflows, what is the professional geospatial community's responsibility and role in ensuring the integrity of GEOINT, particularly concerning the responsible and informed use of these very powerful capabilities?

Analysis as a Process

Other professional analytic disciplines have responded to similar challenges associated with the rapid proliferation of sources, methods, and technology by establishing analysis as a process rather than any specific tool, technology, or method. As a result, professional domains such as medicine have developed training and education that emphasizes higher-order thinking as applied to the infinite variations in circumstances that arise in practice in order to develop the intellectual agility necessary to respond to a complex, rapidly evolving problem space. The GEOINT domain must also move in this direction.

Several years ago, the nascent data science community faced a similar challenge. Recognizing data mining and predictive analytics were more than a single tool, technology, or algorithm, several data science pioneers crossed traditional professional boundaries to collaboratively identify and document foundation-level best practices and requirements. This instantiated a consensus process model that incorporated the identified essential elements of data mining and predictive analytics. This process model supported analytic workflow that set the question or challenge as the forcing function for the overall analytic approach to include selection of specific sources and methods. Moreover, by being source, tool, technology, and algorithm agnostic, these process models could rapidly accommodate novel sources and methods, including those not even conceived of during development of the original process model, as evinced by the ongoing applied relevance and staying power of the original process model in contemporary data science.[1]

While creating process models may appear to be a conceptually simple approach (i.e., state your question; find the data; insert your favorite tool, technology, or algorithm here; get the answer) successful implementation of any model is incredibly difficult, particularly as it relates to developing training requirements. As a result, good data science practice or analysis as a process necessitates training that is significantly more complicated than most vendor-provided courses in buttonology. Good practice requires the critical thinking skills necessary to find the "word problem" embedded in the analytic challenge, select and use the appropriate sources and specific analytic methods, and properly execute the workflow and associated algorithms to find truly meaningful solutions to some of our most difficult problems. Similarly, training that emphasizes analytic process and critical geospatial thinking rather than specific tools or technology supports an approach that lets the problem guide the solution rather than forcing questions to fit a specific methodology or preferred tool. Therefore, there are, theoretically, an infinite number of "correct" analytic approaches. Again, the deep expertise required to effectively leverage specific sources and methods has driven many GEOINT professionals to specialize, which creates unique the unique challenge for our community to balance the need for deep expertise with emphasis on process to ensure the analyst is a problem-solver rather than simply a geospatial technician.

1. The original process model promulgated was the Cross Industry Standard Process for Data Mining. Over time, commercial vendors have created product-specific variations of the model, however these remain very similar; reinforcing foundation-level elements of good analytic process and related workflow.

The "integrated analytic environment" described above suggests the community is moving in this direction conceptually. Training and education can effectively operationalize this model, while also incorporating critical geospatial thinking skills into analytic workflow and process.

Training vs. Education: Developing the Critical Geospatial Thinker

As we consider this problem-solver model we must ask how we will train the analyst of the future to use it and how will we effectively assess their ability to extend from individual sources and methods and the associated technical requirements in favor of this deep, technology-agnostic exploitation and analysis.

This method of letting the problem guide the solution frequently goes against the approach of structuring the question to fit a preferred technology or capability. Often, the technology the analyst knows or feels comfortable using, or even a technology solution an organization has selected as the preferred approach, is used regardless of fit to the problem on hand. The pressure, whether overt or subtle, associated with the desire to get return on what frequently is a large investment in geospatial content and/or capabilities may cause the analyst to go with a specific source, method, or technology. In other words, if all I have is a hammer, then everything looks like a nail (or I will make it look like a nail to align with organization preference and/or justify an expensive purchase). Continuing with the carpenter analogy, GEOINT training should emphasize the importance of analysis as a process, ultimately creating a master carpenter who will have an array of tools in their geospatial workbench.

Structuring geospatial analyst training from an analysis as a process perspective will also build the intellectual agility necessary for future analysts to effectively respond to a rapidly evolving analytic environment, while also positioning them to seamlessly incorporate new sources, methods, and technology into their workflow, including those that have not been developed or yet considered. Some initial steps toward this training have been made, including incorporating analytic methodology and techniques as well as geography theories and models into geospatial intelligence analyst training and education components. Moreover, as described in the NGA 2020 Analysis Technology Plan, "analysts need a unified GEOINT platform that aligns disparate tools, algorithms, and capabilities into an interoperable, data-centric exploitation and analytical system of systems—an 'integrated analytic environment.'" This describes the ideal workbench for the aforementioned master carpenter. While promising, full implementation of this model remains to be accomplished.

Measuring Outcomes

This change in perspective will drive an associated change in evaluation and assessment of the geospatial professional. In other words, how do we measure knowledge and does it matter for all geospatial analysis tasks in all domains? The challenge to the training community and geospatial educators will be to construct assessment tools and methods that effectively measure these problem solving skills and knowledge rather than focusing on "how-to" skills and technical proficiency.

Most proficiency assessments are based on successful execution of concrete and measurably specific tasks, which naturally place an emphasis on technical proficiency. Therefore, in practice, tests often are weighted with lower-order "know-how" skills, even though many instructors recognize the importance of higher-order geospatial thinking skills.

In this model, evaluation frequently measures performance rather than knowledge. As we weigh the difference between technical performance and knowledge, assessment ideally will primarily measure the ability of the analyst to effectively identify and characterize the question posed, and then structure an analytic approach to answer the question.

One question we must answer is: Are education and training requirements different in different domains? As sources and tools become increasingly easy to use and accessible we will need to weigh the relative importance of how-to versus know-how or critical geospatial thinking and knowledge, and whether it is role- or task-dependent. For example, is "how-to" knowledge sufficient for some analyst roles or domains, particularly in the operational setting? Considering increased access to and availability of geospatial content and technology, are critical geospatial thinking skills realistic, practical, or even required for all? Are there some applications and environments where simple performance metrics (i.e., buttonology) will be sufficient?

Science of Multi-INT

In keeping with the democratization of GEOINT—the Science of Multi-INT (SOMI) model is gaining traction. As we have told our colleagues for years, location matters. Everything becomes data and GEOINT serves as the foundation. While this might be true, we may have been too successful in delivering this message given the race to not only embrace, but actively incorporate GEOINT content as the foundation for many SOMI-related efforts. So, how do we ensure balance between the clear importance of location and the necessary requirements and skill to not only understand the geospatial domain, but to use GEOINT effectively and responsibly in support of accurate and reliable decisions?

Are know-how skills sufficient for the use of GEOINT in multi-INT analysis? Who will make that call? And how will access be regulated now that most traditional barriers to entry have been removed? Moreover, as we consider the democratization of GEOINT as embodied in the SOMI concept, we revisit the question regarding whether GEOINT is a separate, unique professional domain maintained through the establishment and enforcement of bright lines and boundaries enforced through training and education, or whether it becomes just another "INT" in multi-INT analysis. Given the success of the "location matters" messaging, it is likely the culture will trend in favor of the "just another INT" model. As that increasingly becomes reality, what role, if any, should the GEOINT Community play in training and education, particularly given the importance GEOINT will play in building the foundation for other INTs?

Future

The future is incredibly bright for the GEOINT Community. A quick review of GEOINT 2020 scopes an emerging profession with tremendous promise. The GEOINT Community embraces the concept of new sources, methods, and technology in support of online and on-demand GEOINT, and the immersive experience where the geospatial environment truly becomes a novel, transdisiciplinary collaboration environment. While Dr. John Snow initially developed this concept during the U.K.'s 1854 Broad Street cholera epidemic, the increasing accessibility of geospatial content and tools is creating a democratization of GEOINT never before imagined.

The first issue the GEOINT Community will be required to address relates to the role GEOINT will play in supporting a unique, transdisciplinary collaboration environment. In the 19th century London cholera example, Snow effectively demonstrated the role of geospatial knowledge, maps, and information as a powerful visualization environment that created the context necessary to support novel approaches to transdisciplinary collaboration. He enabled end users to effectively incorporate their domain expertise and "street-level knowledge" to interpret complex relationships in support of meaningful solutions to some of our hardest problems. Leveraging the unique perspective the geospatial environment brings to visualization enables analysts outside the geospatial domain to effectively incorporate their tacit knowledge and domain expertise to extend results in support of novel insight. Again, this has been anticipated in the NGA 2020 Plan, "visualization capabilities will enable teams to work together in a multi-user visualization environment where they occupy the same data-space and landscape, but with unique perspectives," similar to multi-player gaming. So, the question is not whether professionals outside the U.S. IC will begin to leverage and use GEOINT, it is already happening. Rather, we must ask what it is can we do from an education and training perspective to ensure this increased use of GEOINT ultimately results in more accurate and reliable analysis in support of decisions grounded in good geospatial science and practice.

The second issue relates to preparing the workforce. How does the community maintain the necessary professional requirements to ensure essential, or foundation-level geospatial knowledge so that all end users will incorporate these tools knowledgeably and responsibly? While technical know-how might be necessary to the practice of GEOINT today, is it sufficient for the geospatial professional and if not, how do we as a community address this rapidly expanding divide?

Finally, because location matters, GEOINT will likely form the foundation for multi-INT analysis going forward, particularly in its ability to anchor observations to place and provide an environment for novel approaches to transdisciplinary collaboration. As the logical extension of this model, the Internet of Things will rest on a foundation of GEOINT. Understanding the unique role GEOINT plays in analysis writ large will enable creation of meaningful and effective training solutions and education for GEOINT professionals as well as analysts in other domains that will enable them to not only use the capabilities available today, but seamlessly incorporate future sources, methods, and technologies as they are developed, including those that have not even been imagined. ■

Global Diffusion of GEOINT Data and Capabilities

Introduction

Only a few decades ago, the United States government uniquely possessed the capabilities and expertise necessary to produce what we now call geospatial intelligence, or GEOINT. Since then, the global diffusion of advanced collection technologies (e.g., imaging satellites, manned and unmanned aircraft), along with GEOINT knowledge and tradecraft, transformed the global landscape. Increasingly, the U.S. government, and to a lesser degree, other governments, commercial enterprises, and non-state organizations, can collect geographic source data on a nearly anytime, anywhere basis. This unprecedented availability of temporally relevant data poses the question of how best to translate the explosive growth in collecting geospatial and related data into producing GEOINT, particularly as actionable information for the U.S., allied governments, and other international partnership organizations.

Globalization of GEOINT Knowledge and Tradecraft

The global trend toward ubiquitous geo-sensing involves much more than having highly capable overhead collection systems. It also builds upon many years of cartographic work that produces state-of-the-art geospatial data for maps and charts covering the world. The digital revolution in data has enabled the integration of disparate forms of GPS-tagged data using geographic information systems (GIS). Layered data often captures important aspects of human geography for various civil, commercial, or national security applications, while cloud computing promises a huge boost in computing capability and big data storage.

GEOINT knowledge and related tradecraft is no longer confined to the U.S. government (IC), or even the world's leading military powers. An important indicator of the worldwide spread of interest in geospatial data and analysis was the Pennsylvania State University's recent Massive Open Online Course (MOOC) offering on GEOINT, which drew 21,538 learners from 188 different countries.[1] Additionally, countries such as India are holding GEOINT-specific conferences. While other countries may define geospatial intelligence somewhat differently than does the U.S., the use of GEOINT data and services is the same.

Another important aspect of the international growth and increased interest in GEOINT is ubiquitous open-source data, which offers an important complement to the traditional IC closed system which primarily used classified GEOINT sources. A good example of the growth of open source is Volunteered Geographic Information (VGI), also called crowdsourced data, as an emerging trend influencing future methods for geospatial data acquisition. VGI involves the participation of untrained individuals with a high degree of interest in geospatial technology and information. Working collectively, these individuals gather, edit, and produce data sets. Crowdsourced geospatial data production is typically an open, lightly controlled process with few constraints, specifications, or quality assurance processes.

VGI contrasts with the highly controlled geospatial data production practices of national mapping agencies and businesses. Adoption of VGI within traditional production processes has been a tricky issue, especially for government organizations requiring specific accuracy metrics due to quality assurance/quality control (QA/QC) concerns related to differences in production methods and expertise levels associated with variable, and sometimes unknown, sources. Nevertheless, the growth of social media has dramatically expanded the opportunities for participatory sensing as individuals and groups capture and share geotagged data on a global scale.

Implications of the Diffusion of GEOINT Data and Expertise

The explosion of global geospatial data availability, coupled with the expanding use of this data for myriad applications, is remarkable. So, what are some of the implications of these global developments for the U.S. GEOINT Community?

1. **The information advantage of the few has been reduced.** Intelligence organizations and operational units need to adjust their strategies given a more level playing field. They should also stimulate additional research into ways to sustain or regain information advantages.

2. **There is a tremendous amount of additional data to store.** Will conventional database storage methods suffice, or will new ones using some form of cloud computing need to be developed and adapted for secure use?

3. **There is also a tremendous amount of additional data to analyze.** To be able to increase analytic capacity, either: 1) advanced technologies need

1. Bacastow, Todd. 2015. Geospatial Intelligence and the Geospatial Revolution, Coursera Massive Open Online Course.

to be developed to enable computer-assisted analysis, including target and pattern recognition, deep learning, change detection, and advanced filtering techniques; or 2) many more human analysts need to be educated, trained, and employed. If neither is accomplished, the additional data being collected and processed is simply "dropped on the floor" instead of becoming the basis for GEOINT products.

4. **There is a need to develop new tradecraft methodologies.** Some examples include the fusion of new data types (such as crowdsourced and UAV-collected data) with more conventional data sets (imagery and other forms of geospatial information). Another example is the need for analytic agility in current GEOINT tradecraft to make effective use of both classified and open-source data as circumstances warrant.

5. **There is a concurrent need to ensure the QA/QC of geospatial data and GEOINT analysis.** Being skeptical of crowdsourced data, or any data not from a familiar source, is intrinsic to the GEOINT analyst's job since all data contain errors. There is increased uncertainty around VGI data, specifically surrounding the positional accuracy and validity of this data, which may result from the lack of adequate geodetic control. Such accuracy issues are important because the assumption is if the data is reliable enough, then it can be operationalized into actionable intelligence. Fortunately, research to date suggests VGI may not be less accurate than "authoritative" data.[2]

6. **In the remote sensing domain, it's not just electro-optical (EO) sensors and data anymore.** Additional education and training offerings need to become available to exploit radar, spectral (multi, hyper, and ultra), infrared (IR), and even cyber. And the focus should not only be on a single imagery type, but also on the use of multiple types of sensors for a given problem.

7. **Additional geospatial data gathering and processing regulations need to be considered to protect individual privacy concerns.** This should be considered at the local, national, and international levels to reassure decision-makers and the public such geospatial data gathering will not have an adverse effect upon individual privacy rights.

8. **Finally, operational entities (military, business, individual) need to increase and/or modify their denial and deception techniques.** With more people having more ways to access relevant data, more protection should be employed to maintain an information advantage.

Conclusions

The global diffusion of additional geospatial information and data is changing the practice of GEOINT. Ultimately, this development can be a good thing, a bad thing, or more likely, some combination thereof. Regardless, the diffusion of GEOINT knowledge, tradecraft, and capabilities will inevitably continue to accelerate. Therefore, planning for the many source implications listed above and taking necessary implementation actions is needed to ensure positive outcomes for the U.S. and its allies. ■

The World According to GPUs

Speed and agility to develop, discern, and display information is arguably the most critical part of GEOINT. Graphics Processing Units (GPUs) have historically been synonymous with systems that require high-end video rendering. Commercially, rendering typically happens in video games. In government spaces, rendering is linked to things such as 3D modeling and high-resolution maps.

When the GPU was designed, it was simply a processor that rendered pixels very quickly. Pixels are nothing more than tiny, colorized rectangles that are the basic building blocks of digital images. The faster the processor, the clearer and smoother the image looks as it changes. One of the critical GEOINT visualization performance components is that GPUs aren't rendering just one pixel—they are rendering thousands, sometimes millions, of pixels simultaneously.

As technology advances we have learned that processing highly dynamic pieces of information quickly and at scale is incredibly useful for decision-making. As GPU use has taken off, many in the commercial world have begun to modify their business models to take advantage

2. The reference source for this observation is provided by Todd Bacastow. See Haklay, M.; Basiouka, S.; Antoniou, V.; and Ather, A. (2010) "How Many Volunteers Does It Take to Map an Area Well? The Validity of Linus' Law to Volunteered Geographic Information." *Cartographic Journal*, the, 47(4), 315-322. doi: 10.1179/000870410X12911304958827

of these emerging capabilities yielding many use cases for this technology. However, the U.S. government and its greater IT infrastructure still have not embraced the use of GPUs. An important question is) How will GPUs impact the growth and integration of technologies in the U.S. government GEOINT space if industry develops revolutionary technology dependent on systems the government provides its users?

Computational processors, also known as CPUs, are specifically designed to provide the horsepower to run extremely complex and linearly dependent mathematical equations. The catch with GPU-specific processing is it isn't designed to process extremely complex pieces of information that require a lot of linear calculations, such as an algorithm. Rather, GPUs are designed to process an enormous number of little pieces of information very quickly. And for the longest time, Moore's Law and the increase in processor speed meant we never really seemed to reach the boundaries of CPU-based processing. CPUs are restricted in the sense that each CPU is broken down in the number of cores (processors). Each core is only capable of processing one piece of complicated computing at once, making them analogous to the part of a computer that can conduct "heavy lifting." Since most CPUs are comprised of around eight cores, you are limited in how quickly you can sift through large amounts of data. GPUs by contrast have dozens, and sometimes hundreds of cores. These cores are not nearly as capable at the computational level as CPUs, but they are analogous to the phrase, "many hands make light work." If a job requires continuous complex and linear-based processing, CPUs will always be at an advantage; however, if the job requires a lot of small tasks completed quickly then GPUs provide those many hands.

In the past five years, the concept of big data has proliferated (with big data defined as many data sources that might be useful to answer GEOINT questions) and Moore's Law has slowed down. There has been a rebirth of sorts in the methods used to tackle large data sets at scale. For example, if an analyst only needs to pull one specific type of information many times over from a massive data set, instead of using a traditional computational processor, he or she can now use these massively parallelized processors to extract data at much faster speeds, with less overall computing resources and vastly reduced power and memory. Industry has taken this a step further in creating software code baselines such as Compute Unified Device Architecture (CUDA) and Fastest Fourier Transform in the West (FFTW). CUDA is a parallel computing platform and application programming interface (API) model. It allows software developers to use CUDA-enabled GPUs for general purpose processing—an approach known as GPGPU. CUDA is the way for a software developer to turn the GPU into those "many hands" for things other than traditional visual images. FFTW is a "C" subroutine that is open-source language used for similar data types as processed by CUDA.

There have been many recent examples in the U.S. government where GPUs have provided an increase in capability that is not video specific but is much faster. The most notable example is LiDAR, where GPUs have proven their ability to develop LiDAR point clouds, which is simply the plotting of tens of millions of little digital push pins in the 3D space at orders of magnitude faster than previous CPU processing. Take the process of computing Fourier transforms on thousands of one-dimensional functions generated by a coherent LiDAR system. For example, processing on an NVIDIA GPU card with 5760 cores will provide a linear estimate of time to process based on the number of samples, while a standard eight-core CPU workstation processing time will increase exponentially. The break-even point in processing time would be around 700,000 samples, or 2.8 megabytes of data, taking roughly five seconds to process. When we look at four million samples taking up 16 megabytes of space, the CPU takes roughly 57 seconds compared with the GPU's 25 seconds. Looking at the extreme of one terabyte of data using this model, the GPU will process in 0.0012 percent of the time it takes the CPU. Once LiDAR points are processed, the GPU does a much better job at displaying them. The speed to display the points to a screen varies with the number of cores in the CPU, but with the GPU processing cited in the aforementioned example, the display speed can be improved by as many as three orders of magnitude.

Since the plotting of points on a LiDAR point cloud is not computationally intensive, the GPU is capable of completing the job using its "many hands" in a fraction of the time. Additionally, GPU processing improves video analysis in ways other than just simply rendering images. GPUs are used to catalog the pixel type and positions in automatic target recognition (ATR) algorithms, which can then be quickly compared to other libraries of pixels to find similar matches. It is easy to simply link GPUs to video processing, but in this example the GPU is doing much more than processing and rendering video, it is also cataloging and indexing information. Once that information is indexed, it is compared to existing indices and matches are produced. This type of processing would never be conducted outside of a CPU a decade ago. Today, Google and Bing use GPU processing to return search engine results more quickly, and high frequency traders use GPU processors to get millisecond advantages over one other. Many of the most advanced raster, ATR, and deep/machine learning algorithms also use GPU code baselines such as CUDA or FFTW.

As the U.S. government works toward advancing its IT infrastructure for the future it has turned to cloud computing as both a cost and resource reduction technique. Equally as important as managing cost is the ability to provide large amounts of processing on demand. GPUs have been adapted to this use case. Additionally, major cloud integrators such as Amazon and Microsoft are beginning to sell server side GPU processing as part of their architectures. Intel, NVIDIA, AMD and Qualcomm have all started cloud instances where developers and engineers can send information to their enterprise GPUs for processing-as-a-service. This adaptation to market pressure is the hallmark of commercial industry. Unfortunately, the U.S. government operates on requirement cycles that need hardware before it can be implemented at scale. In short, demand has to be at a fever pitch before the supply is even considered.

GPU processing is a perfect fit for the needs of a U.S. government GEOINT user. The U.S. government could take advantage of the speed of data processing and high throughput capabilities of GPUs applied to GEOINT data. For example, government-collected LiDAR rendered by GPUs can be, and in some places is, processed and displayed within minutes of collection, a process that used to take hours or days. ATR can be done at scale using indices of hundreds of thousands of video files via GPU-based technology. Everyday software developers in private industry are adapting GPUs for data mining, voice recognition, machine learning, and many other uses.

GPUs are a key pillar in the future of high-end GEOINT computing, and now is the time for the U.S. government to develop plans that allow for the integration of this capability into its infrastructures.

This integration can take place as the government works to identify the best tool for the best job, whether that is CPU or GPU. The government must also work to identify the emerging fields where their interests, such as machine learning, 3D printing, and computer vision, intersect with cutting-edge GPU usage. Next, the government's knowledge managers must partner with experts to conduct a thorough review of its data types that are well suited for GPUs, such as LiDAR, video, and voice. By gathering an understanding of the scale of potentially GPU-enhanced data, the government will be well armed with facts on how best to invest in future growth. Industry is leading the way on GPU processing in two critical areas: 1) determining fields for use; and 2) developing enterprise capabilities to allow for proliferated use of the technology. The U.S. government can assist in driving innovation in critical fields and pattern its adoption of the technology after industry. ■

High-Resolution 3D Mapping: Advancements in Technology & Impediments to Implementation

3D Mapping: A Historical Perspective

Cartography is an ancient craft and with few exceptions it has used some form of flattening as its main display paradigm. The momentum of centuries has carried mapping across the threshold of numerous technical innovations without substantially changing what defines a map. Within the GEOINT discipline we have seen improvements in mapping accuracy and changes in how we create, publish, analyze, and view geographic information—yet we still widely use flat maps in a 2D computational framework.

2D GEOINT advantages such as mature data standards, portability, and computing performance are partially eclipsed by missed opportunities in human factors associated with usability, cognitive learning, and particularly "spatial memory"[1] among consumers of 3D GEOINT.

3D GEOINT lends itself to an egocentric or "first-person" perspective, which facilitates spatial memory. This is why training simulators use 3D models and employ various immersive 3D viewing environments. 3D computer modeling, including 3D visualization, is a mature technology nurtured by a large community including architects, engineers, animators, radiologists, biotechnologists, and, to a growing extent, geospatial professionals. The modeling and simulation community has taken advantage of 3D GEOINT and computer modeling to perform specialized tasks in training and mission rehearsal.

1. Ruotolo, Francesco (2009). *Spatial Memory: The Role of Egocentric and Allocentric Frames of Reference*. In: Spatial Memory: Visuospatial Processes, Cognitive Performance and Developmental Effects, pp. 51-75

Geologists were among the earliest adopters of 3D mapping technologies using seismic data and voxel modeling to view the Earth's interior. Architects create detailed 3D Building Information Models (BIMs) from laser scans. Specialized software, data formats, and standards have developed around these and many other niche 3D modeling applications.

So, why hasn't the GEOINT Community fully embraced 3D computer display and modeling in the same way as architects or mechanical engineers? The answer has much to do with tradition, cultural inertia, and, to a lesser extent, technological barriers. The map archetype is uniquely two-dimensional. Even Google drew this distinction with its Google Maps and Google Earth products.

Cultural explanations might weave together institutional norms, the digital revolution, and free market forces. Academic geography departments around the world were quick to embrace 2D digital mapping, image processing, and geographic information systems (GIS). Mapping agencies added electro-mechanical, digital encoders, and soft-copy stereo photogrammetry to speed up the map-making process while meeting existing standards. Commercial software companies made moves to garner market share. Out of this construct came a new workforce with unique skills built around a small number of popular 2D GIS software products—all inheriting the flat map tradition. While all of this was going on, other communities were more fully leveraging the digital revolution to develop methods of creating, viewing, and analyzing the world using true 3D mapping and modeling.

3D Revolution?: A Future Perspective

LiDAR is one of the more disruptive technological advancements to directly impact GEOINT. With LiDAR we are producing unprecedented amounts of data that will only increase as the variety and efficiency of LiDAR systems grow. LiDAR modalities include specialized payloads for airborne topographic and bathymetric mapping, vehicle-mounted mobile mapping, and human wearable or handheld devices for interior mapping, to name a few. The next generation of single photon-sensitive LiDAR detectors is here and these can map 10 times the area at twice the resolution in the same amount of time. A new generation of commercial linear-mode LiDAR sensors has arrived that are more efficient than ever.

The convergence of computer vision and mapping has led to explosive growth in automated 3D GEOINT. Algorithms such as semi-global matching for 3D scene reconstruction developed by the computer vision community are now part of standard photogrammetric software. Without any specialized hardware we can now create high-density, colorized, (passive) point clouds and fully textured meshes directly from street-level, aerial, and satellite imagery. These 3D, textured models could replace segregated imagery and elevation rasters as the new foundation data layer in 3D GIS applications. 3D objects automatically derived from the foundation model could replace 2D planimetric vector features in 3D GIS applications.

Our ability to ingest, render, analyze, and distribute high-resolution 3D data is also growing. The technology is not so new but its popularity is expanding quickly. The private sector has a great deal of choice with new open-source libraries and rendering engines specifically for point clouds and other 3D data. The market dominant software giants are also rolling out new 3D GIS engines. Given this cultural and technological evolution, why isn't everyone using 3D? In addition to bureaucratic hurdles, there are both technological and functional deficiencies of 3D software.

The do-it-all 3D GIS-enabled software suite is still a relatively new concept. While software capable of 3D mapping has been around for decades in the form of CAD, globe-based viewers, and other specialized tools, none have the full capability to replace current 2D GIS software suites. CAD software is very precise but also not made for viewing and analyzing large regions of the world. On the other hand, globe-based GIS viewers are designed to do just that; however, they lack the precision and robust functionality offered by current GIS software. There are many existing tools that allow us to create rich content for simulators and gaming engines, but these tools also lack the functionality to support complex decision-making and multiple analysis functions.

In the public sector there are hundreds of thousands of installed desktop (thick client) GIS applications. Most public sector organizations carefully select and certify GIS software and make further investments in training and tightly coupled hardware infrastructure, relational database management systems, and data development. When new COTS software versions are released it can take the public agency years to adopt it. Most public agencies cannot just download the latest/greatest 3D viewer to install on a work PC either. There is also the matter of how legacy data will perform in a 3D viewing framework or understand the art of the possible when requesting new high-resolution 3D data or commercial data acquisition services. Colleges and universities have also been slow to modify and update their programs to support 3D training.

The paradox that the solution is also the problem presents the greatest market barrier. For example, 3D GIS would help this agency work with all of this new point cloud data but it cannot be installed because of policies or incompatibility with legacy hardware or data; or that agency can install 3D GIS software but it cannot afford to acquire good new 3D data to use with it. Fortunately, demand for 3D data is quite high and supply is being magnified through better interagency data sharing which should energize further demand for better 3D GIS tools.

Practical Considerations

When considering investments in 3D mapping, whether for data, software, or both, users and managers should take the time to understand the true costs and benefits to our mission. As a GEOINT Community, we should understand it is much easier to use 2D data in a 3D application than 3D data in a 2D application. The analytic workforce should work proactively with the software and hardware industries to develop cross-cutting requirements, specifically for 3D mapping and not simply react to what is new and hot coming out of other disciplines or market sectors. We must also help the U.S. Intelligence Community understand the concept of operations for acquiring high-resolution 3D data is different and may not fit into existing tactics, techniques, and procedures or scopes of work.

High-resolution 3D terrain information has and will always constitute a foundation level data layer whether in 2, 2.5, or 3D software applications. 2D data files such as elevation rasters and 2D map viewers are still highly efficient ways to store, manage, and view terrain data. Knowing and planning for the trade-off between abstraction and efficiency is important. High-resolution 3D data pays off when detail, context, and learning retention matter the most.

The market will lead the way. Software developers and equipment manufacturers will continue to demonstrate the art of the possible. There is diversity in the markets as they serve other 3D mapping and modeling communities. New 3D mapping functionality will organically find its way into existing product lines. End users and support agencies within the GEOINT Community will pull harder when the mission demands outpace or exceed existing commercial capabilities. As an example, consider the growth of high-resolution imagery and LiDAR that began with Buckeye data from the Army Geospatial Center.

Conclusions

A 3D spatial framework should be the most natural state for GEOINT because it is the most accurate way to model the world. Architects and engineers take full advantage of CAD 3D modeling yet still create convenient, portable, 2D breakouts in their final design packages. Unlike CAD, the majority of current geospatial tools and techniques—even the ones that create discrete 3D data—are still constrained by 2D mapping paradigms. There are many tools to create stunningly accurate renditions for specific places and phenomenologies; however, there is currently no solution that combines the broad functionality of current 2D GIS with the richness of 3D models and the precision of CAD. Demand is growing rapidly for full 3D textured mesh models and better software for its use. All segments of the GEOINT Community should work together to develop requirements and implement solutions. Most of the capabilities exist and could be rapidly adapted and deployed with appropriate funding and acquisition support. All signs indicate we will get there eventually. Yet how we get there must not be to the exclusion of traditional mapping methodologies. ■

Small Satellites, Commercialization, and the Rapid Evolution of the Industry

While Sputnik was technically the first small satellite (small sat[1]) to be launched, more recent efforts to produce viable and valuable small sat constellations have been ongoing at some level for more than 20 years. The technology initiatives begun under the "Star Wars[2]" part of the National Missile Defense efforts emphasized size reduction to enable large constellations of anti-missile systems to be orbited affordably. While such a system is no longer a priority for most planned missile

1. Typically you will see small satellites abbreviated to either "SmallSat" (usually indicating a title, name, or specific class) or "small sat" (usually used to describe a more general overarching idea of small satellites). For consistency, we will use the terms "small sat" (singular) and "small sats" (plural).

2. The Strategic Defense Initiative revealed by President Ronald Reagan in 1983 and nicknamed "Star Wars" by the media.

defense capabilities, the improvements in miniaturized guidance systems, thrusters, sensors, cryocoolers, and other components have been insinuated into the space industry, enabling realistic Small sat designs.

The "Star Wars" work 20 years ago foreshadowed a revolution in the race to space now led by commercial companies. Well outstripping government's ability to lead this race, the commercial world grasped the value of space to commercial markets such as agriculture, finance and business intelligence, and energy. Nanosatellite and microsatellite market size is estimated to grow from $889.8 million in 2015 to $2.52 billion by 2020. Driven by this reality, the market is in a frenzy to meet these new—primarily commercial—opportunities.

Small Sat Revolution

On Oct. 8, 2015, a United Launch Alliance Atlas V rocket carried 13 CubeSats as a secondary mission to the launch of the National Reconnaissance Office's primary payload. The Atlas V rocket delivered 13 Government Rideshare Advanced Concepts Experiment (GRACE) CubeSats to orbit. The nine NRO-sponsored CubeSats and four NASA-sponsored CubeSats were mounted to the Aft-Bulkhead Carrier, located on the back end of the Centaur upper stage. These satellites were a combination of government, academic, and commercial designs.

On Dec. 3, 2015, NASA launched an Orbital-ATK Cygnus Commercial Resupply Services mission atop an Atlas V rocket. That launch carried with it three CubeSats, selected through the CubeSat Launch Initiative (CSLI) for two universities and one primary school as part of the ninth installment of the Educational Launch of Nanosatellite (ELaNa) missions. The CubeSats will be deployed from the International Space Station (ISS) via the commercially operated NanoRacks CubeSat Deployer (NRCSD) system.

Additionally, in October 2015, NASA's Launch Services Program (LSP) awarded three launch contracts for CubeSat dedicated rides to Rocket Lab USA, Firefly Space Systems, and Virgin Galactic.

In 2014, Planet Labs announced its intent to launch 100 CubeSats into space in 12 months using a flexible and easily reproducible design that can deliver three to five meter resolution.

These examples are just a sampling of ongoing small sat activity. All of this rapid change and growth creates an exciting time for both small sat providers and small sat data users while presenting challenges and opportunities for government agencies.

Challenges and Opportunities

While it might have had sole ownership over this domain for many years, governments can now leverage a burgeoning industry that extends well beyond spacecraft launch. Streaming data from space and persistent coverage over key points on the ground open up many possibilities in the area of Big Data analytics, automated data processing, analysis as a service, and more. Government agencies can take advantage of new applications developed to solve commercial market questions. And, all of this focus on commercial small sat data will give rise to new data analytics fields and experts whom government agencies can team with.

New markets and new technical small sat developments will result in small sat data users experiencing growing pains and encountering problems in data quality, consistency, and accuracy. But over time, commercial organizations and government agencies together can work through these growing pains that will increase the overall reliability of sensors, sensor data, automated processes, and the resultant analytics.

With the growth of commercial small sat fields, government can shift its focus to the next 20 years of space technology and let the commercial world do what it does best—drive the market of possibilities in this new small sat world. In partnership, government and commercial providers are on the cusp of a brand new world—in space.

Annex: How Small is Small?

Since assured system performance has always been the principal concern of satellite developers and acquirers—and until recently reliable components were heavy and expensive—the only serious consideration of size was in the realm of physical launch envelope. Typically, the more redundancy designed into a system the better. The real change affecting the space community resulted from the lowering of cost-to- and cost-on-orbit of the systems. Whereas loss of an individual traditional satellite cost hundreds of millions of dollars, the intent of miniaturization (and interchangeability, component standardization, and the other changes in concept) is to make the loss of a system affordable, therefore allowing more systems to be orbited. This potential proliferation enhances both survivability and access opportunities for the resulting systems, and is therefore highly desirable.

Defining small sats by size and weight: The usual protocols for characterizing satellites are to describe their function (i.e. imaging, meteorological, navigation, communications, etc.). Since each type was a unique build involving little component interchangeability, this was and in many cases remains a reasonable method. With improvements in interchangeable parts and the evolving ability to launch many elements at once, an additional schema for describing systems by weight and volume becomes useful. The term "small sat" for vehicles less than approximately 600 kilograms, "MicroSat" for spacecraft between approximately 10 to 200 kilograms, and

"NanoSat" for spacecraft weighing less than 10 kilograms, all imply differing levels of redesign (sometimes radical) and reimagining of manmade satellites. One logical binning method is to describe each system in terms of how many can be deployed from a single launch opportunity.

Why the buzz about CubeSats? CubeSats represent the most mature thinking on the new focus on making as much of a satellite design re-useable as possible. An assembly line of nearly complete subcomponents only requiring the addition of a sensor, antenna, or some other mission component would substantially alter both the development timeline for systems and the cost-to-produce, since it would allow for the first time real economy of scale and learning curves in production.

Innovations

Standards:
The government user has to prepare as he or she looks toward small sats as complimentary collection opportunities for the challenge of standards, particularly the standardization of small sat architectures. It is not enough for government customers to merely concentrate on data standards. Government customers must have an awareness and input into the full system architecture to guarantee maximum flexibility and maintain high capabilities while minimizing costs. Bus standards, communication standards, and Command and Control (C2) architecture standards should all be considered when scoping the requirements for the mission to make sure capabilities match the needs.

Developing standards for systems in early research and development is a significant challenge. There are several key reasons why this is so, but the primary reason is that when technology is under development, competing implementations have different advantages and problems (remember VHS and Beta?). Choosing a standard for an evolving capability places limits on the solutions that sometimes result in reduced performance. Many companies desire the additional funding that comes from the sale of proprietary solutions, and the satellite business has many of these.

As the tech base for components both matures and is altered by the number and nature of non-proprietary manufacturers of elements such as solar cells, ion thrusters, and gyros, the opportunity to standardize and commoditize market components is occurring.

Costs:
Cost is a principle driver in small sat architecture, and the GEOINT Community must make smart decisions to fund the right solutions that minimize cost escalation but not capability.

There are two types of cost models the government GEOINT customer should review before making investments: government owned and operated small sat communications architectures; and commercially owned and operated small sat architectures. Government owned architectures allow for cost sharing between government organizations and combined investments to maximize capabilities compared to monies spent.

The downside to government owned architectures is priority of mission between the primary government sponsor and other government customers. Customers may not have the ability to make the changes they want to maximize their mission potential when those changes have adverse effects on the larger architecture.

Commercially owned collection architectures have many advantages for a government customer who only wants data. Procuring data from a commercial source allows the government to purchase what it wants without being directly responsible for the long-term operation and maintenance of the system. Procurement from multiple commercial vendors will allow diverse data ingestion into the NSG, but data purchase will be at a premium cost since commercial vendors will have burdened costs that take into consideration operation and maintenance of the architecture, technology upgrades, and personnel costs. The burdened costs could lead to less of a cost savings than envisioned compared to the capabilities the small sats deliver. This cost model has not yet evolved.

Commercial improvements & breakthroughs:
Relying on the commercial industry is the proper way forward for innovation in the development of the subcomponents of a small sat. There are many government-sponsored laboratories, university affiliated research centers (UARCs) & federally funded research and design centers (FFRDCs) that can drive prototypes and tackle hard design problems. Commercial companies not only participate in the technology creation process but can also be relied upon to increase quality in the manufacturing process with faster technology refresh rates.

However, the small sat industry is still technologically immature. Commercial-off-the-shelf (COTS) material usage is ideal when designing small sats, but many of the parts aren't made for use in space. Most of the COTS material used in small sats are manufactured for other purposes and still do not have the highest quality in manufacturing. Performance of the parts can vary per manufacturing batches. Component designs for parts, such as the radio or onboard processor, are still immature and many are manufactured directly for the mission in a manpower intensive way. This also leads to opportunities for human error in the manufacturing process and drives up cost.

The size limitations on miniaturizing sensors intended for use in space-to-ground operation derive from physical constraints. Optical resolution (the smallest system achievable object focus) is a function of the effective diameter of the telescope doing the observing, and the smoothness of the mirrors or lenses focusing the light. This is the reason engineers are always pushing to increase aperture and improve polishing/grinding techniques. A potential solution to support miniaturization of an imaging sensor system would be to develop an inflatable or deployable optic, but achieving the requisite smoothness from such a system remains challenging. The positive arc on all the technology challenges that exist in the present state is that with many organizations working small sats the maturation of technology will arrive fairly rapidly.

Direct tasking and receipt:
With the ongoing proliferation of imaging small sat solutions, the opportunities to reshape the use of remote imagery for conduct of tactical operations are increasing. For a price, and with appropriate priority, time-critical users such as first responders may soon have the ability to select locations for imaging from the satellites directly. This would enable observation of the most important targets, such as current fire locations, and allow more efficient tasking of locally controlled airborne observers. There is still a time lag in getting data in the hands of end users, but over time demand will alter the protocols for at least some systems' data delivery. In addition, the larger, traditional imaging systems' data feeds require significant massaging to be readily interpreted. New standards and mass produced cameras are mitigating that problem so data will be more immediately useable.

Need to operate space in a contested environment (resilience):
While space is becoming more accessible to a broader set of users, it is also proving to be a more contested domain. China is openly working to develop and demonstrate systems to attack space infrastructure in order to deny information about their areas of interest, and several other nations are working on concepts to jam or disrupt signals that enable tactical operations. A major advantage of small sats in operating through such environments is the physical proliferation they represent. To block image collection from one camera is relatively easy, but to do so for several systems taking data at the same time is not—the signal sent to block one bird is a beacon to others watching. Also, to attack a satellite requires approaching it, and with each system in a different orbit, stopping more than one is kinematically difficult, if not outright impossible. Therefore, if space resilience is a U.S. goal, as President Obama has indicated it is, small sats are a valuable contributor to this aim.

Examples of Venture Capital Investments

Several companies have stepped into the sandbox of small sat development in the last few years, in ways that lend real credence to the likelihood of some, or all, reaching stable commercial success. Following are short summaries of a few of the 2015 front-runners.

Skybox Imaging: Now a Google subsidiary, Skybox provides commercial, high-resolution satellite imagery and high-definition video from CubeSats. They have several launches scheduled to develop their constellation in 2016 and 2017.

Planet Labs: Based in San Francisco, Calif., the company designs and manufactures triple-CubeSat miniature satellites called Doves that are then delivered into orbit as passengers on other missions. Each Dove continuously scans the Earth, sending data once it passes over a ground station. Once fully populated, the system will provide 3- to 5-meter resolution imagery for most sites on Earth at approximately 3 p.m. each day.

BlackSky Global: The company plans to provide color imagery at a resolution of 1-meter ground sample distance (GSD) at nadir. BlackSky's spacecraft will be predominantly located in mid-latitudes to provide frequent revisit over 90 percent of the Earth's population. BlackSky's constellation will complement existing satellite imaging service providers and enable a new level of global awareness by providing dynamic change detection across multiple industry sectors. Their constellation will consist of the launch of 60 imaging spacecraft beginning in 2016, with the goal of completing the constellation by 2019.

Urthecast: Based in Vancouver, Urthecast entered the remote sensing community by placing cameras on the ISS. They now plan to place a 16-satellite constellation in orbit to image the Earth. A truly international construct, Urthecast will have sensors manufactured by Surrey Satellite Technology in the United Kingdom and ground control functions developed in Spain. Their stated goal is to make large amounts of Earth observation imagery from multiple sensors, and place the data in a user-friendly, cloud-based platform available for people to process. Urthecast's proposed constellation intends to pair an optical satellite (to view the Earth in visible light) with a radar platform (with which to image the ground, in any weather, night and day).

Why Does the U.S. Government Care?

The role of the U.S. government in remote sensing is evolving. Whereas commercial remote sensing in the 2000s was nearly completely available due to government subsidy or outright ownership of platforms, the next generation systems described above neither rely on (nor in many cases expect) federal resources for their business cases. As these systems enter operation, there will most certainly be a competition for customers, but in that competition the U.S. government is less likely to be treated as the premium customer. Instead, premium status might be given to the largest procurer of data, not solely based upon whether the user is U.S. government vs. a foreign government vs. commercial. The U.S. government may find itself gaining advantage only with guarantees of large data purchases from vendors, and those guarantees may minimize the cost savings imagined by government acquisition officials. The government will need to evaluate a collection strategy that looks at a mix of both government and commercial collection to maximize return on investment when compared to needs.

Moving Forward

The one certainty in the realm of small sats is there will be a great deal of dynamism in the next several years, and the community will benefit from a much greater quantity of quality remote sensing data. While these emerging small and microsatellites will provide unprecedented access to remotely sensed imagery and dramatically improve persistence and resilience, none are the perfect solution to satisfy our national security needs. They each have strengths and will support many applications and needs across the community. However, we need to think of these as one in a system of systems, where they will compliment and work with national, large commercial, and airborne imaging systems. The government's challenge will be to aggressively take advantage of these new small sat capabilities while finding the right balance with existing space-based and airborne collectors to form a truly integrated collection and analytic capability to meet the security needs of the U.S. and its allies. ■

Shifting GEOINT Capabilities

Without argument, geospatial information services, location-based social media applications, and geospatial intelligence capabilities have exploded in use and acceptance in the last decade. Prior to the 1970s, geospatial practices were largely government funded and required great skill and expertise. During the last decade, there has been a significant shift in the source of investment driving geospatial technology and innovation—largely coming from commercial-based capital investments.

For decades, the government led innovation in this country, seeding industry in various ways to obtain capabilities primarily critical to national security. Often working in secrecy, these investments and innovations were world class and incredibly productive. Industry leaders such as Northrop Grumman, IBM, and Hewlett-Packard were largely directed by government activities such as the race to space, development of defense weapons, long-range missiles, and advanced arms needed during the Cold War. Today's GEOINT innovation environment is largely driven by capitalist endeavors. Investments are made in technologies and processes related to personal movement, social connectedness, and freedom. The bottom line is the reduction in U.S. Government (USG) led or mandated/directed innovation has been replaced by private investment and commercial market expansion. Additionally, the USG's inability to keep pace with technical geospatial innovation has been exacerbated by declining budgets and an antiquated acquisition process.

In 1983, President Ronald Reagan decided to make Global Positioning System (GPS) capability freely available for civilian use. This decision came in the wake of the Korean Air Lines Flight 007 shoot down, in which it was determined the aircraft had drifted into Soviet Union airspace. In 1989, the first of a new GPS satellite constellation was successfully launched. The 1972 advent of Landsat opened the public to the notion that remote sensing had much to offer myriad use cases including environmental, agricultural, and land use. By the mid-1980s the French began selling over-head imagery commercially, and the Soviet Union followed suit in the mid-1990s. This opening of an emerging commercial market drove a change in U.S. national policy, which included development of a commercial imagery policy. The U.S. began granting commercial satellite imagery licenses in 1994, enabling Lockheed Martin to launch and operate IKONOS.

In 1983, Microsoft launched Windows. With this launch came the regular, everyday use of personal computers and the Internet and digital age began to take shape. In the early 2000s, mobile communications and personal devices in combination with new compute power put easily accessible data, positional and visual, in the hands of individuals.

In 2014, there were nearly 1.8 billion registered users on social media and more than 7.1 billion mobile devices—more than there are people in the world. In the past, world leaders and those who sought to change the world could only reach as far as the technology of the day would allow them to communicate. Now that reach is literally worldwide and immediate, and events that unfold in seemingly faraway places are felt around the world. Through the use of our devices and ubiquitous communications, the human condition and ability to discover and relate to events has made the world more connected. It is this increase in every user and device becoming a sensor that has resulted in people relating to one another as never before—the concept that "they are like me and their problems are my problems" has become real. One could wonder whether one element important to the events of the Arab Spring was related to the ability of people in different regions to see that others shared their frustrations and sentiments. In other words, my neighbor's backyard is only greener if I can see it—and if I can see how bad (or good) I have it.

Innovative players in the commercial GIS and remote sensing industries are rapidly diverging from the original USG baseline of a decade ago. New players with new business models, such SmallSat companies Skybox Imaging (now owned by Google), and Planet Labs have risen with the promise of scanning the globe multiple times a day. Tellingly, their business model is significantly focused on consumer demand and selling to commercial buyers rather than the U.S. government.

The USG's inability to accept commercial solutions to GIS challenges stems from a cultural antipathy to procuring commercial solutions. The Federal Acquisition Regulation has been modified over the past decade to mandate consideration of commercially available solutions, but any impartial assessment of the acquisition programs in the past several years will show that commercial solutions are rarely adopted. Another factor is the USG's reluctance to ingest unclassified GIS data into classified networks and to allow USG analysts everyday access to this rich and diverse pool of data.

As a result, the USG GIS user base has to make do without data sources common to everyone else in the world. The commercial capabilities commonly available on smartphones are not available to a USG GEOINT analyst. The geospatial tools, imagery, and geospatial data products currently available to USG intelligence analysts are largely the same as they were for analysts more than a decade ago.

And the rate of divergence between data available to everyday, Internet-connected users and USG GEOINT analysts will continue to widen. By 2016 or so, SmallSats will be able to take images of any place on Earth twice a day—all with just a half-dozen satellites. By the time its entire fleet of 24 satellites has launched in 2018, Skybox will image the entire Earth at a resolution sufficient to capture, for example, real-time video of cars driving down the highway.

Another example of the shifting focus globally for geospatial capabilities is Uber, the social transportation service that is completely reshaping the way people look at taxis. Uber is a transportation system that relies on drivers and passengers to interact via a location-based application. In addition to actually paying for a desired service, there is a social contract based on rating and scoring that continues the propagation of the platform. Recently, in an effort to gain better global access to mapping and GIS capabilities, Uber made a bid to procure Here (the most used online mapping capability in the world). The initial estimate of the acquisition is approximately $3 billion. This purchase will not go without challengers. There is also a report that a group comprised of BMW, Daimler (Mercedes-Benz), and Baidu (a Chinese search engine company) are interested in buying the mapping capability. Google and Apple are also interested. Geospatial capabilities—largely due to the proliferation of mobile devices and location-based applications and social media—are big business.

There are also a significant number of small businesses providing relevant GEOINT capabilities in a niche or boutique mode. Two examples include MapSense, a San Francisco-based company that performs entity extraction from spatial data, and Thermopylae Sciences + Technology, a Northern Virginia-based firm that builds search and visualization capabilities on Google Earth layers, allowing users to selectively dive into web map service layers with capabilities such as i-Spatial.

There is also a non-revenue, social explosion occurring in the geospatial and mapping space. OpenStreetMap (OSM) is a crowdsourcing (also known as Volunteered Geographic Information, or VGI) group that enables updates to maps, which are provided for no fee. OSM has developed a new iPhone application, Scout, that enables users to provide updates to the maps. Recently, Telenav, a wireless location-based services company, announced plans to incorporate Scout and provide more updated maps to users.

The U.S. federal government seems to be missing out on the revolution, not because they do not see value, but rather because they do not seem to be able to shift their policies, processes, and methods quickly. While the USG is performing some measure of migration and adoption to commercially developed and available geospatial capabilities, those efforts could be much broader, faster, and prolific. There are a couple of factors limiting the more rapid adoption of these capabilities.

First, the federal geospatial information services and U.S. DoD/IC GEOINT market often claims government needs cannot be met by commercial capabilities or data. The USG also states they require changes at a velocity not met by commercial capabilities. With the advent of crowdsourcing and crowdsourcing techniques, this is no longer the case. Capabilities such as OSM, i-Spatial, and Tomnod not only demonstrate the ability to crowdsource data—but to also collaborate on quality and accuracy in an incredibly fast manner. These capabilities place a premium on access to data in direct opposition to the production model that many cartographic capabilities maintain as necessary—that it is about the product, not the data. In the new use space, users wish to control what layers and data sets they review, and use data sets when and how they want to use them versus the model in which the quality assurance data production chain stipulates mandatory use. These capabilities, due to the nature of being commercial and the need to meet consumer demand, maintain they must be deemed accurate at the data element layer.

Second, when considering commercial applications, standards, and capabilities, there is little debate time over the critical element of place. It is simply not enough to know where we are—or where an activity occurs—rather we need to know where and when. Increasingly, the need to understand specifically where and when an activity occurs is critical. This is also true of USG precision engagements in the battle space. Accuracy with regard to time and place is critical and needs to be addressed.

Third, U.S. policies limit adoption of capabilities developed outside the U.S. The world is developing geospatial technology at a rapid rate and innovation is a global force. The USG, in an effort to put U.S. industry first, is limiting the rate of innovation and adoption in some ways due to policies that limit the use and procurement of foreign-developed capabilities. The USG and supporting commercial companies need to be able to trade ideas and capabilities and partner with allies and cooperative parties to maintain any semblance of technological edge.

When considering International Traffic in Arms Regulations (ITAR) restrictions, it is not simply that the USG acquisition processes are poor but that its laws and policies restrict use of the very technology enabling this explosion of available geospatial data and information. Because many of these geospatially-enabled technologies—and even derivative information products such as high-spatial resolution electro-optical imagery—are not available to be sold outside the U.S., American companies are greatly restricted from pursuing commercial markets otherwise open to all companies (or government-funded efforts) operating anywhere but within the U.S. These ITAR restrictions also limit the ability of foreign companies to do business within the U.S. but have no impact outside the U.S.

The processes the U.S. government currently uses to procure and acquire capabilities are slow and cumbersome. Federal procurement rules are set up in a manner to prevent corruption and create an environment of fairness, ensuring taxpayers get value and all competitors are equal. These processes, while necessary for some procurements such as aircraft carriers, show little distinction to smaller software buys. Some of these processes have been significantly shortened—but have a long way to go to keep up with the pace of the commercial space.

There are various other issues associated with USG hesitancy to adopt some capabilities, including privacy issues and the need to maintain secrecy to protect collection methods and national security interests. Place is fundamental to almost every discussion in each individual's life. Almost as fundamental as language is the concept of where I am, where others are, and where my needs can be best met. There will continue to be a discussion on the balance between "geolocation privacy"—location I'm broadcasting—and the need to know if there is a credible threat. This is certainly a difficult set of issues that will continue to be debated.

This look at GEOINT, geospatial information systems, and remote sensing clearly demonstrates we may be at the beginning of the explosion of capabilities that will allow us to gain a deeper understanding of each other on a global scale. The real impacts to full utilization of these capabilities in support of national security, national policy development, and global awareness... The following recommendations to USG GEOINT policymakers and leaders are as follows: First, implement a true, open, data service approach to data integrating externally available data and applications. Second, implement a more transparent approach to GEOINT—allowing for more disclosure of what the government knows, utilizing openly available data and how it really impacts the nation and national interests. Third, implement a faster process to adopt commercial applications in a freer manner, which may include a different business and procurement model. Finally, establish policies that embrace more openness to foreign developed capabilities and data services models.

This is a critical time in the world's history. The globe is more connected than ever while natural resources are becoming scarce and populations worldwide are becoming less sustainable. Only through real openness and collaboration can the energy generated during crises be focused in a positive manner for the collective good. This is really a time to capitalize on the power of GEOINT and the importance of place.

Investments, primarily private, being made in current geospatial information systems and geospatial intelligence capabilities worldwide, demonstrate the success of GEOINT and rapidly occurring information. The opportunity is ripe for the U.S. federal government to take advantage of these new capabilities and advance its support to national decision-makers, first responders, warfighters, and citizens. ■

GEOINT Beyond the IC: Academia, Training, and Certification

Since the rebranding of the National Imagery and Mapping Agency (NIMA) to the National Geospatial-Intelligence Agency (NGA) in 2003, the GEOINT discipline has been defined by the needs and missions of the United States Intelligence Community (IC). The IC is beginning to implement new professional certifications for a subset of federal government personnel. Meanwhile, industry, government (federal, state, and local), and academic partners are supporting development of a new universal GEOINT professional certification administered by the United States Geospatial Intelligence Foundation (USGIF). The USGIF certification is being psychometrically developed to quantify capabilities of contemporary analysts in four GEOINT areas: remote sensing, geographic information systems, data management, and data visualization.

Three GEOINT stakeholder communities—government, affiliated industry partners, and academic research/education partners—advance GEOINT ideas and capabilities based upon government requirements for myriad national and human security challenges. This stakeholder input is especially important for tackling 21st century security challenges requiring significantly greater analytic agility because these challenges come in many forms at much finer social resolution. What was once a niche discipline of IC cartographers and photogrammetrists in the 1970s and 1980s has simultaneously become the sophisticated, high-tech analytic discipline known as GEOINT. The discipline has also evolved into the ubiquitous, high-tech, consumer-grade geospatial search/knowledge capability available on any networked data-tech platform, quickly becoming an essential element of everyday life. The immediate availability of geospatial information in handheld devices, in the navigation systems of cars, and with embedded attributes in blog comments and posted images on social media have all helped democratize human life in a spatial sense with location-based (GEOINT) information.

This broad, organic democratization of GEOINT is changing the discipline's very definition, and in the process expanding its use, nature, and applications. GEOINT practitioners now exist both within and external to the U.S. Intelligence Community. GEOINT democratization is causing fundamental changes in IC operations, as evidenced by NGA Director Robert Cardillo's recent decision to push more analyses into open-source realms, with increasing transparency for selected human security challenges. This paradigm shift is forcing the IC to play catch-up as it integrates technological innovations in mobility and social connectivity at a time when GEOINT innovation is increasingly driven by private rather than U.S. government development.

In the 20th century, U.S. government GEOINT activities included launching billion-dollar satellites to collect high-precision intelligence data. Today, there are growing numbers of lower-cost, commercial satellites and unmanned aerial systems capturing data in various forms, collecting billions of pixels and generating a flood of geospatial data and actionable information. Further, intelligence derived from overhead imagery is increasingly augmented with actionable knowledge derived from massive amounts of open-source data. As a result, GEOINT is expanding from an exclusive IC domain toward a broader and more open community of analytic activities, increasingly supporting commercial needs.

The rapid growth of GEOINT analytic capabilities and usage across a variety of competitive commercial environments has created associated demand for highly proficient GEOINT practitioners. This increasing demand for well-educated GEOINT practitioners means colleges and universities are rapidly updating curricula to address the challenge of cultivating new generations of GEOINT professionals that not only comprehend contemporary matters of human conflict and human-environment interactions, but are also endowed with the ability to understand the impacts and consequences of human actions.

GEOINT capabilities are increasingly employed within the broader communities of public safety, homeland security, disaster management, and commercial business. This transformation has substantially diminished the notion of GEOINT as an IC-only occupation, and lessened any perceived professional jurisdictional control associated with the federal role in this community. GEOINT professional preparation has gone beyond task, condition, and standard as previously set by the IC. GEOINT learning in higher education, for example, focuses on the more universal aspects of problem-solving with remote sensing, geographic information systems, data management, and data visualization capabilities, and does not focus on bureaucratic matters esoteric to the U.S. government GEOINT enterprise. Graduates from collegiate GEOINT programs bring fresh energy and creative thinking to GEOINT challenges—characteristics that merit cultivation within the IC's analytic workforce.

GEOINT is a multidisciplinary applied science domain. Considerable scientific knowledge associated with GEOINT sub-disciplines is developed and subsequently taught openly at universities around the globe, further constraining the IC's ability to set and define terms. This professional practice paradigm is somewhat analogous to the medical profession, in which students blend academic knowledge with practitioner knowledge as they learn by doing. This approach prepares professionals within a dynamic, real-world learning environment that rewards mental agility.

National security activities exist within a somewhat complicated system of interrelated jurisdictions. In the case of GEOINT, these jurisdictions were initially defined by NGA domain responsibilities, but these limits are now challenged by applications of public safety, homeland security, disaster management, and even business intelligence (far beyond the purview of national governments). With the GEOINT genie now well outside the bottle, it is incumbent upon the academic community to continue advancing the GEOINT discipline with innovative education and research.

Professions maintain disciplinary jurisdiction via oversight of professional practice and knowledge. Credentialing provides the means to maintain high professional entry standards and enforce continuing education requirements to ensure ongoing professional competency. Certification follows a "know how" paradigm that assumes requirements can be identified, taught, and observed in evaluation. The "know how" paradigm is contrasted with the knowledge paradigm. The knowledge paradigm allows the profession to redefine its work, defend its jurisdiction from interlopers, maintain the agility to seize new opportunities, and recognize the continued advancement of an individual's expert knowledge.

GEOINT analysts synthesize many forms of geospatial data to create actionable intelligence from geospatial data, leveraging capabilities in remote sensing and imagery analysis, geographic information systems (GIS), geospatial data management, and data visualization to produce deliverables for more effective decision-making. It is synthesis across these varied areas to create actionable knowledge that distinguishes GEOINT from its sub-disciplinary pillars. GEOINT is increasingly practiced as data science with a human security focus, creating analytic value beyond the sum of its core disciplines.

Despite common GEOINT emphasis on data and technologies, people remain GEOINT's most precious analytic resource. Today's GEOINT professional describes, understands, and interprets to anticipate the human impact of an event or action. GEOINT analytics now routinely involve analysis of activity locations and times using remote sensing, GIS, data management, and data visualization, employing an intelligence tradecraft approach to collaboratively synthesize actionable knowledge from geospatial data, and submitting concise analytic reports that can inform better decision-making.

The GEOINT Community stands at a major inflection point. GEOINT continues to experience a revolution in technology, policies, organization, doctrine, training, education, and, perhaps most importantly, public acceptance. Any past reluctance among academics regarding the GEOINT discipline is evaporating with increasing awareness of GEOINT's value proposition. More and more universities are recognizing the benefits of updating geospatial science/technology curricula to match current GEOINT workforce requirements.

There's no going back now—GEOINT has grown beyond IC constraints. Humankind faces heightened security challenges and will benefit from stronger analytic capabilities. Gone are the days of predictable and monolithic threats to global security. Geospatial analysts now need the intellectual agility to analyze spatial population/environment characteristics within a location or region, as well as the ability to detect cultural anomalies that might reveal potential threats to human security. Maintaining high professional standards via top-quality collegiate education in partnership with substantive professional credentialing can help guarantee the next generation GEOINT analysts remains analytically sharp. ■

Essential Elements of the GEOINT Toolkit: Evolving Human Geography to Meet GEOINT Tradecraft Needs

In the last several years, GEOINT tradecraft has seen significant change due to rapid advances in technology developed to respond to various types of crises across the global landscape. Demands placed on GEOINT practitioners have been met to some degree by the rise of new and evolving areas of study in universities, innovations in available technology, on the job refinement of skills, and a growing commercial need for simpler, integrated methods of incorporating community behavior into analysis and research related to spatiotemporal research. The need for new applications, expertise, and scholarship in human geography—the study of people and their cultures across location, activity, and time—will continue to move GEOINT specialty fields toward mainstream scholarship. The study of the recent rise to power of extremist group Daesh is an example of how GEOINT analysts provide value-added understanding of this threat through geospatial visualizations. However, richer analysis of current global challenges such as Daesh requires innovations and methods that capture information beyond current events, to include historic, cultural, environmental, and economic dimensions. The human geography discipline contains a set of tools useful for researchers and GEOINT analysts to better describe, assess, and aid understanding of pertinent issues.

Why Human Geography?

A snapshot of the last century portrays a world fraught with conflict given the diverse religious, cultural, and ethnic heritage of regional populations coupled with changing environments, economies, and politics. An understanding of the human landscape is required to better manage and respond to the rise of religious extremism and reoccurring cultural tensions and conflict. Human geography can assist GEOINT analysts in describing and analyzing global change in a scientifically rigorous manner that, when combined with modern geospatial visualization tools, can be readily communicated to a larger audience.

When nations are called upon to support humanitarian efforts and maintain security and stability, it is increasingly important for both government and industry decision-makers and analysts to understand the organization of key groups in a society, relationships and tensions among groups, ideologies and narratives that resonate within groups, group means of communication, societal leadership system, and group values, interests, and motivations[1] —all key elements of human geography.

The Challenge

Long understood by academics, recent events have given rise to debate about the art and science behind the human geography discipline, which encompasses a broad set of terms, applications, and analysis methods that focus on capturing and describing the relationship between humans and their environment, particularly with respect to resource use. Human geographers use visualization tools to tell the story of these complex, resource-centric dynamics in a simplified manner, readily accessible to the lay-person, policy-maker, or warfighter. Today's GEOINT analysts and operators need to understand cultural dynamics, particularly when supporting or operating over complex and urban terrain—whether conducting modes of regular or irregular warfare, stability operations, patterns of life, communications trend analyses, or providing humanitarian assistance or emergency response.

Sustaining the U.S. Intelligence Community's focus on human geography requires establishing and maintaining a foundation of training, increased knowledge, innovative applications to emerging problems, and documentation for future generations of analysts. Whether used as a primary research source or leveraged with other technologies, and whether used strategically or tactically, human geography provides valuable insight to analysts across disciplines and is a key component to understanding human activity related to the Earth's physical features and geographically referenced activities.

Context Through Human Geography

Human geography data provides strategic insight into power structures by including historic, cultural, economic, environmental, and/or political context. As an example, the Arab Spring created government power vacuums in Egypt, Libya, Yemen, and Iraq, which occurred simultaneous to the weakening of the

1. Petraeus and Amos (2007), The US Army - Marine Corps Counterinsurgency Field Manual, page 40.

Taliban, decentralization of Al Qaeda, and decline of U.S. involvement in the region. This regional destabilization allowed Daesh to rise to power, filling the vacuum in an already unstable and conflicted region. Today, Daesh evokes four themes of its Caliphate: 1) fragmentation of the Islamic world; 2) intervention of the "oppressors;" 3) geopolitical acts of eliminating and destroying borders and the nation-states they define; and 4) symbolic opposition for the ideologies and powers Daesh opposes.[2] This agenda is a reflection of the region's tribal, political, ethnic, and religious history. The sovereign boundaries, which were created in the wake of the 1916 Sykes-Picot Agreement, do not capture and contain the social boundaries of the Middle East, and have introduced a breakdown of indigenous norms of thought, behavior, and social relationships. These breakdowns are manifested in social, political, religious, and economic conflict throughout the region. Human geography offers analysts the necessary context to work through complex regional and national security issues.

History shows that, when conflict or environmental change force people to move from their home, people return, whenever possible, to their point of origin. The current Syrian refugee crisis provides many tactical examples. The Daesh offensive in Ayn al-Arab in September 2014 caused the mass migration of more than 400,000 refugees, almost the entire civilian population, seeking shelter in the nearby Turkish towns of Suruc, Sanliurfa, and surrounding refugee camps. The subsequent migration caused massive economic loss (studies estimate the damage at approximately $5.2 billion in 2014), with increased social tension between refugees and the Turkish host community, especially in cities hosting large numbers of Syrian refugees. The coalition of Syrian, Kurd, Arab, and American forces began to retake the region in 2015 and displaced refugees started to return home as villages were liberated and violence subsided in the region.

The United Nations' resolution to turn off the tap to extremist funding is intended to take aim at the Islamic State, shutting down access to the international financial system necessary to move money and import supplies critical to Daesh operations. Countries that fail to comply could potentially face sanctions, including the freezing of assets that stem from oil smuggling.[3] The consequences of undermining the economics behind the oil trade, with increased military actions targeted at Islamic State oil infrastructure, is intended to create the economic shifts that will disrupt Daesh, but will also impact the captive populations in Syria and Iraq subject to Daesh extortion. Identifying allies within the Islamic community who oppose Daesh is also critical to counter the Daesh narrative and muster the political and military might to suppress Islamist terrorism.[4]

Viewed across a region, analysts use human geography to uncover the extent of tribal and cultural influences irrespective of international boundaries, shedding light on the undercurrents of the political landscape. In the case of North Yemen conflict in 2011, the international linkage of the Hashid and Bakil tribes (and related groups and prominent individuals) brought to light a better understanding of the regional politics and the continuing Saudi Arabian influence in Yemen.[5]

Analysts seeking to understand the flows of people and their effects on regional stability must have insight into homeland locations and also understand the fundamental aspects of societal relationships in the regions in order to understand people's influences and patterns of life as well as to perform trend analyses and provide context and understanding for decision-makers. By itself, geospatially and temporally enabled human geography data provides analysts a deeper understanding of prominent people and groups in their social network and locations. However, human geography data can also be leveraged with other data sets or technologies supporting activity-based intelligence. In the aftermath of the November 2015 terrorist attacks in Paris, France, human geography data analytics provided context by revealing the relationships of bad actors. Similarly, human geography data provides insight into the connections of groups and individuals to help mitigate risks, for example, by avoiding transgressors and their close contacts, or by understanding and diffusing potential conflicts between employee groups.

Recent history has proven the central importance of understanding and incorporating human geography in GEOINT analyses so decision-makers can execute appropriate, well-informed, and timely decisions. The stakes are high, as regional stability and economic impacts to all invested parties hang in the balance. It is necessary for the continuous development of an integrated GEOINT analysis curriculum that brings human geography and other disciplines together—analysts of the future will need to integrate multiple disciplines to understand the human landscape and provide the best available information. And while these new, integrated curricula are being developed, analysts must continue to use all available data, including human geography, to accurately provide appropriate context to answer the questions posed to them. ■

2. Tinsley, Meghan, ISIS's Aversion to Sykes-Picot Tells Us Much About the Group's Future Plans, April 23, 2015 http://muftah.org/the-sykes-picot-agreement-isis/#.Vi9p6rerTq4
3. Solomon, Jay, (Dec 16, 2015), Wall Street Journal, http://www.wsj.com/articles/u-s-russia-to-offer-u-n-resolution-seeking-to-cut-off-islamic-state-funding-1450293245
4. Plaster, Graham, (Nov 16, 2015) TheIntelligenceCommunity.com https://www.linkedin.com/pulse/how-defeat-isis-graham-plaster
5. Cordesman, Anthony, Rethinking the Wars Against ISIS and the US Strategy for Counter-Terrorism and Counter-Insurgency, Sep 28, 2015, http://csis.org/publication/rethinking-wars-against-isis-and-us-strategy-counter-terrorism-and-counter-insurgency

Bringing Transparency to Transparency

The Fundamental Concern

Transparency is a partnership of governments making information openly available and citizens putting the information to use. The Global Positioning System (GPS) is perhaps the quintessential example of transparency. GPS has enabled a culture change and is "powering" GEOINT. Ironically, impacts of GPS transparency are so complete and embedded in current smartphone culture that the average citizen no longer "sees" or appreciates the shared government information in the form of ranging signals. GPS, originally intended for military and intelligence applications during the Cold War, was made available to the civilian community by the U.S. government so aircraft, shipping, and transport around the world could fix their positions and avoid straying into restricted foreign territory. Today, GPS is indispensible for positioning and route finding for drivers, map-making, and academic research. It is particularly significant that this partnership adds value to the partners, including the Intelligence Community. We would not have the massive volumes of crowdsourced geospatial data without ubiquitous GPS technology.

This paper is intended to start a dialogue concerning the implications of transparency for GEOINT within the U.S. government. This dialogue will help us understand the consequences of transparency for U.S. government GEOINT activities. These discussions will ensure the GEOINT tradecraft continues to uphold the highest levels of intelligence data accuracy and the end consumer's confidence that transparency can continue to be indispensable for advancing intelligence processes.

A Sense of Transparency

In January 2015, while a Massive Open Online Course (MOOC) about GEOINT was underway, a forum thread was created for students to discuss the recent article, "Can You Have a Transparent Spy Agency?"[1] Within hours, there were 175 posts and 1,181 views. NGA Director Robert Cardillo's message was and continues to be, "where we [NGA] can, we are giving you our products and, we are giving you our tools so you can create your own products. And with our products and our tools, we hope to enable you to achieve the consequences that you need."[2] There is a great deal of uncertainty about transparency within the U.S. government's GEOINT activities. One word frequently mentioned in the forum was "consequence." As we pursue this paper's goal we will use MOOC forum posts to highlight some of the students' thoughts and concerns.

A fundamental question is what does transparency mean? The word transparency has been in public and political discourse since at least Watergate in the 1970s. Finel and Lord, noted authors and experts in the area of government transparency, define transparency as:

> "[T]he legal, political, and institutional structures that make information about the internal characteristics of a government and society available to actors both inside and outside the domestic political system."[3]

Mitchell extended this definition to include:

> "Underlying this thought is the idea that the citizenry must be active participants if transparency is to occur; it is not enough for governments to simply publish information."[4]

These definitions of transparency can be summarized around three core concepts: openness, communications, and accountability. Openness implies obtaining information without obstruction or concealment, meaning it is accessible and not secret. Communication implies a relationship between government and citizens built on trust, mutual benefit, and reciprocity. Accountability is the acknowledgment and assumption of responsibility for actions including the duty to report, clarify, and be responsible for any consequences.

The Value of Transparency

The value of being transparent is often so obvious it is overlooked. In February 2015, the Director of National Intelligence (DNI) published the "Principles of Intelligence Transparency for the Intelligence Community" (Principles). NGA's public websites hosting unclassified geospatial intelligence data, products, and services in support of U.S. and international relief efforts in Liberia and Nepal are a recognizable example. Nevertheless, to many, transparency and intelligence seem

1. Tucker, Patrick. 2015. Can You Have a Transparent Spy Agency?. DefenseOne, January 22. 2015, http://www.defenseone.com/technology/2015/01/can-you-have-transparent-spy-agency/103554/
2. Cardillo, Robert. 2015. Address at the Esri Federal Users Conference, Washington, DC, February 10, 2015.
3. Finel, Bernard I., and Kristin M. Lord. 1999. "The Surprising Logic of Transparency." International Studies Quarterly 43, no. 2:315–339, p. 316.
4. Mitchell, Ronald B. 1994. "Regime Design Matters: Intentional Oil Pollution and Treaty Compliance." International Organization 48, no. 3:425–458.

to be mutually exclusive. Intelligence is associated with secrets and the notion of transparency is openness. Secrecy, which is often contrasted with transparency as an ideal, has negative connotations and is often associated with spying and espionage. However, as Mark Lowenthal points out, viewing intelligence as primarily secret misses the important point that intelligence is ultimately information that meets the needs of a decision-maker.[5] Likewise, it seems we might be missing the important point that NGA's transparency initiative is about building trust—we will discuss this more later.

In reality, total transparency is unnatural and seldom occurs. Humans conceal aspects of their lives from others due to fear of inappropriate use of the information, embarrassment, retribution, denunciation, harassment, or loss of employment. GEOINT's tradecraft is an organization's sources and methods. GEOINT sources may include information obtained clandestinely and analytic methods are those techniques used by analysts to extend understanding of an intelligence concern. An organization's geospatial sources and methods may be closely guarded so as not to give opponents the opportunity to know the capabilities and interests of an intelligence organization.[6] To quote a student that posted to the GEOINT MOOC[7] forum:

> "The reason we have non-transparent intelligence agencies is to seek out that which is meant to be hidden and to not necessarily announce that something has been found, in order that it may be observed, destroyed, or otherwise countered…"

There are also those that believe when NGA uses the term "transparency," it refers to the ease with which NGA not only can help society with data and expertise but also maximize the collection of information for government purposes. As an example, consider this quote from another GEOINT MOOC student:

> "It appears to me they [NGA] recognize the private sector is making huge advancements in 'persistent' surveillance and they want to capitalize on their fast growing technology and analytic capability, throw in crowdsourcing to boot. In other words, transparency applies when it's coming in from the outside."

Underlying this thought is reality and an idea. The reality is that in addition to the traditional sources and their emerging commercial counterparts, there is a tremendous amount of digital information that is freely generated and left available to both the public and NGA, but steps have to be taken to transform it from data, to information, to knowledge that can drive decisions. The idea is that the world's citizenry will be active participants as an NGA source. The risk is that transparency may improve NGA's access to data but not equally add value to the public due to the necessity of keeping sources and methods secret. The value proposition does not meet the expectation of the customer, in this case, the public.

Worth the Risks?

Notwithstanding the societal expectation, two major dynamics are at work to make transparency worthy and necessary. These changes are: 1) the nature of the threats; and 2) the availability of commercial and open-source data.

GEOINT analysis, products, and services are needed to better understand the threats of today—which include violent extremism in the Middle East and Africa, Russian aggression, the rise of China, Iranian and North Korean nuclear weapons, cybersecurity, energy and water resources, and population destabilization concerns. Most of these threats are less observable and embedded in the larger mass of human activities. The result is the old paradigm cannot meet intelligence demand. The future calls for a continuous flow of geospatial data from open and closed sources that can be used in near-real time. GEOINT developed from open sources has become essential with increasing interest toward the geospatial "Internet of Things"—that network of physical objects embedded with electronics, software, sensors, and network connectivity.

The second force of change is the end of the U.S. monopoly on GEOINT sources. According to Cardillo, NGA "must open up GEOINT far more toward the unclassified world … in the past, we have excelled in our closed system. We enjoyed a monopoly on sources and methods. That monopoly has long since ended. Today, and in the future, we must thrive and excel in the open."[8]

NGA faces a challenge as open and commercial sources exceed the utility of closed sources in the general sense. Due to a change in the utility of sources, NGA is being forced to shift intelligence production from a few closed sources (e.g., imagery) to a large number of open sources (e.g., commercial imagery, social media, etc.).

There is a strong argument that the utility of closed source information has and will continue to decrease relative to open-source information. This notion is based on the exponential growth in the volume and variety of open-source information. A significant implication is that the improved accessibility of open-source

5. Lowenthal, M. M. 2015. Intelligence: From secrets to policy (Sixthition. ed.). Los Angeles: CQ Press. p 1.
6. Principles of Intelligence Transparency (Implementation Plan), Director of National Intelligence, October 27, 2015.
7. Bacastow, Todd. 2015. Geospatial Intelligence and the Geospatial Revolution, Coursera Massive Open Online Couse.
8. Cardillo, Robert. Remarks for AFCEA/NGA Industry Day 2015. Monday, March 16, 2015

geospatial information has leveled the GEOINT source playing field globally. This is not to suggest that closed sources, or national resources, are not needed. It is, however, to suggest that closed sources will likely concentrate on specific needs where open sources are incomplete or are applied to corroborate possibly deceptive information.

Implications and Considerations

We live in an era where everything is under scrutiny and government is expected to offer solutions to some of society's most immediate and entrenched problems. Further, current national security threats and the availability of commercial and open-source data are forcing change. The truth is, transparency is nothing new as a fundamental tenet of our democratic society and we need to understand how to operate in the open ecosystem. The following is a brief discussion of select implications and considerations related to the concept of transparency.

Loss of total information control: Following from the proposition that the U.S. GEOINT Community will experience a shift in intelligence production from a few closed sources to a large number of open sources, many of which are volunteered. Loosening of controls could lead to and require partnerships, open collaboration, efficiencies through expertise pooling and knowledge transfer among collaborators, or it could lead to group biases, data leakage, lack of opponent surprise and for some, an uncomfortable lack of total information control. Significantly, a consequence of a shift to open-source data is a redistribution of responsibilities for collecting, maintaining, and analyzing data.

In relation to open-source data collection, it invokes the image of a self-organizing, self-governing, adaptive, and nonlinear community of suppliers. To be responsive, the collecting organization must harmoniously blend the purpose and cooperation. This will require development and acceptance of a different business model—something other than the past contractor/vendor relationship. A clear, constructive purpose and compelling ethical principles shared by all participants are essential for volunteers to be willing to spend their time helping create data or information products.

Crowdsourced geospatial data (also called Volunteered Geographic Information, or VGI) involves the participation of untrained individuals with a high degree of interest in geospatial technology. Working collectively, these individuals collect, edit, and produce data sets. VGI production is typically an open, lightly controlled process with few constraints, specifications, or quality assurance processes. This contrasts with the highly-controlled geospatial data production practices of national mapping agencies and businesses.

Here are a few thoughts about managing this shift:

- There seems to be no U.S. IC organization currently using predominantly the open-source model.
- The challenge is not an information problem; it is an organizational problem. New leadership concepts and organizations are needed.
- On the cycle that progresses from data to intelligence, production is easy when there is a stable source environment. When change is occurring quickly, such as when using open source, it is very difficult to move beyond the data.
- The bottom line with external relationships is trust.

Organizationally, start by defining the purpose then stating the principles, identifying the people, developing the concept of relationship structure for the organization, and writing a charter.

New data sources: Intelligence data resources are rapidly changing in quantity, quality, and complexity—additional sensors on multiple fronts are not all created equal for accuracy and content or in how to successfully apply mathematical algorithms to different types of data to prevent false pattern matches or inaccurate conclusions. Existing traditional data resources are well understood, implicitly trusted, carefully modeled, and current exploitation tools are tailored to work with them. Traditional U.S. intelligence (or GEOINT) analysts are highly skilled and trained individuals who work hard to refrain from introducing bias and error into the reasoning chain by following tradecraft rules. VGI, on the other hand, contains a lot of personal judgements hinging on localized perceptions and cultural understandings and limited information sources. How are these data sources to be successfully merged and synergistically mined?

Current pushes for the advancement of tipping/cueing are hard pressed to find useful interfaces of information exchange between the traditional, baselined sensor types. How is this to be accomplished with the influx of different sensor personalities emerging from the wings? How can a piece of crowdsourced data that doesn't follow specific format or content rules become part of a consistent tradecraft that is repeatable?

The challenge is that information created or obtained by these disparate sensor types does not equally map across the spectrum of information to create a cohesive, understandable, and calibrated story. Each type of information has to be handled independently to understand its faults and biases. When you combine similar but not calibrated information types you no longer fully understand the explicit error being introduced into the story and you can easily draw inaccurate and non-traceable conclusions.

With these arguments in mind, what standards and new processes need to be considered to take full advantage of the data storm? How will the IC work to combine the data in meaningful ways? How will manual or digital systems keep track of accuracy and error? How will the IC understand when the error overwhelms the results and creates information that is untrustworthy?

Persistent coverage: With the storm of data sources comes the potential for the U.S. government to watch high value targets with persistence. With this additional data also comes a larger, more powerful toolkit of intelligence-deriving options. The key to the consideration of the value of persistence is the above pervading argument of comparison, mapping, and calibration of the utilized data sources. More data is not always better if it is not prepped for proper comparison across the data spectrum. Extensive coverage of high-value targets sounds powerful, but the data gathering is only the first step in the process of deriving intelligence value. If the data is provided in cross-compatible formats, processed correctly for maximum accuracy and error understanding, makes the best use of manual and digital information extraction methods, and is correlated into a GEOINT narrative that sources all judgements and derived intelligence conclusions and states all applicable biases and error, then more data will translate to more depth of knowledge. If rigor and tradecraft initiatives are not introduced that address these concerns, then more data is simply more data and not more intelligence.

Manual versus automated analysis: More data also introduces the discussion of machine data analysis to help mine the exponential increase in data volume. How to determine content and data quality as well as how to train computers to extract intelligence tips, queues, and value since all additional data under consideration cannot be handled via traditional, established analysis methods become key considerations for the community to discuss. New processes and paradigms for next level intelligence extraction from raw data sources needs to be defined. Methods of data sorting and model training for machine level analysis will need to be validated and incorporated into standard workflows. Key human interaction points will need to be determined to ensure critical decision points are still managed by human intellect to in turn ensure intelligence that is appropriate to the situation. What is the appropriate division of work between computers and humans (pattern detection versus sense-making)? How will the Intelligence Community adapt training and tradecraft to encompass these new workflows and how will the crowdsourced data that does not conform to this rigor be allowed to compete and compel the GEOINT narrative being formed? Can we create metadata tagging or traceability weighting to inform our final judgements in the value of the end intelligence products? Can machine-derived intelligence (also understood as Big Data mining) eventually become the norm and be trusted as much as traditional analysis? Many new processes and policies need to be discussed to harness the newfound power implicit in the storm of data and to provide consistency of tradecraft and intelligence products for the future.

GEOINT narratives[9]: As both traditional (closed) and non-traditional (open) intelligence sources become available, data can be woven into powerful narratives. It is possible that the mix of closed and open sources cannot be fully understood without using "activity" as the construct. The idea departs from conventional GIS approaches in which location is the basic spatial data construct. The idea also departs from social or psychological approaches with persons as the basic units of analysis that attempt to characterize individuals or their aggregates.

An activity is a combination of who (actors), when (time), where (place), and what (purpose). A temporal sequence of activities with coherent purposes becomes a story drawn from many sources. The embedded plot emerges by connecting activities over space and time. Geospatial storytelling is to make sense of activities and their potential collectives. Hence, using "activity" as the organization principle of information is to seek, enable, and store data as a quadruple (actor, time, place, action) and additional information may be attached as necessary, such as significance, purpose, or decision. The activity data serves activity-based intelligence (ABI) analysis from multiple angles to develop geospatial narratives.

Central to the idea of geospatial narratives is the sense-making process for reaching spatiotemporal connections. Isolated activities cast the potential thread of motivation, purpose, and implication, while activities emphasize happening and may or may not center on persons. The narrative is a sequence of events constructed into a meaningful story.

Pertinent to intelligence issues, stories can be of considerable intelligence value. But, there are unanswered questions about standards and how to define intelligence accuracy. Do we provide advisory metadata on the reliability of nontraditional products and data sources?

Next Steps

Viewing GEOINT as secret misses the important point that intelligence is ultimately information that meets the needs of a decision-maker. NGA's transparency initiative is about building trust within the ecosystem of openness and collaboration. This ecosystem must include the notion of collaboration between analysts in different groups, analysts in different agencies, and agencies and the public if we are to reap the value of transparency.

9. The following text is drawn from an unpublished 2012 paper by Dr. Todd Bacastow, Ms. Susan Kalweit, and Dr. May Yuan.

If implemented disingenuously, or with a hidden agenda or motivation, the move toward transparency could have negative implications. It could result in distrust and cynicism, especially if the value of the information shared or motives of participants come into question. A major challenge is citizens must be active participants in the process if transparency is to be successful.

U.S. intelligence agencies need to inform and educate the public regarding processes and procedures without revealing sources and methods. While complete openness and transparency is not practical with regard to intelligence agencies, simply publishing data on a website is insufficient. Agencies need to provide the context in which the data were collected and their intended use. If this occurs, two-way communication becomes possible, resulting in greater sharing of open-source and social media information.

However, this new wealth of information must still be evaluated for its accuracy and validity with regard to its intended use. Intelligence agencies are held accountable for their actions, regardless of the sources of their information. If NGA makes the open-source information available for use, do they implicitly gain some culpability for the accuracy and truthfulness of the data? They must act within ethical and legal boundaries. Agencies need to review their legal guidelines and privacy policies to ensure they adequately allow for transparency while still maintaining accountability and integrity.

This article is a modest attempt to start a discussion concerning the potential of harnessing the power of public data and understanding the growing GEOINT culture while still not losing the best lessons learned within the Intelligence Community. ■

GEOINT as a Service

The explosion of geospatial collectors and data is driving the demand for immediately consumable geospatial information. Gone are the days of raw data being the currency of the realm. And while big data analytics, location-based analytics, and geospatial data visualization are widely used terms describing hot topics, it is *results* decision-makers seek, not process.

The vast majority of all data now created has a location and time. As a result, the geospatial data environment is on the cusp of persistent analytics and information. Driven by insatiable consumer hunger for geospatial information and business needs to create revenue-generating applications, all industries are now constantly demanding more timely, location-based information to make best-informed financial decisions. As a result, commercial companies are cracking the code on persistent geospatial data analytics-as-a-service. These companies are conducting analysis through sophisticated algorithms best performed by machines, not just providing the raw data someone else has to analyze. Integrated multi-source GEOINT analysis also unifies normally disparate information to enable new decision insights.

This burgeoning commercial market space is opening the door to rethinking how geospatial or location-based analytics are performed. Profitable geospatial intelligence-a- a-service (GaaS) offerings currently exist in commercial agriculture, insurance, finance, urban planning, fisheries management, and many more business verticals. To be viable (e.g. profitable) emerging analytic services will require dramatic changes in current thinking by a variety of stakeholders, which include government practitioners and providers, the geospatial industry, and academic institutions. These stakeholders need to address key questions about current approaches in order to stay relevant. Past practices relied primarily on proprietary internal processes to create GEOINT. Today's stakeholders must make major changes to current business models to become savvy consumers of GEOINT shared services.

Becoming an organizational consumer of GEOINT-based services offers a huge potential upside but means past approaches, even those from only a year or two ago, may not be as effective as newly spawned techniques, and will require a strong tolerance for consistence process change. The biggest beneficiaries of this type of rapid change are organizations in the areas of global focus, efficiency, repeatability and consistency, analytic visualization, and machine learning. Rapid and continuous adoption of GEOINT-based services will allow organizations to drastically change business models and not have to do everything they've previously done for themselves. Letting go and trusting other providers for a level of sophisticated analysis beyond just foundational or repetitive operations will be a major adjustment. Embracing this level of trust as normal business will ultimately allow decision-makers to address an increasingly complex and ever changing array of interconnected challenges on a global scale.

Companies that have long supported the geospatial field will be able to improve some of their current approaches and shed services that will no longer be needed. Selling raw data is passé as a primary business focus. Instead, data companies are being asked to create immediately consumable, geographically enabled information products. Making GEOINT information consumable will require constant change and improvement to the GEOINT infrastructure. Geospatial data, rich in content and massive in size, occupies large amounts of memory and requires much computing power. Advanced geospatial analytics will require commensurate changes to networks, storage, data management, and processing. There will be room for many commercial players in this emerging paradigm if they are willing to offer innovative solutions and provide a different kind of supporting infrastructure to the persistent geospatial data and analysis environment. The demand for new algorithms, analytic tools, the ability to integrate multiple sources, and development of commercial applications to realize actionable information is already huge and will continue to grow. Partnerships revolving around analysis, data capture, storage, processing, and visualization will form, dissolve, and reform more rapidly.

This evolution of the doing and consuming of GEOINT will also require creation and adoption of innovative business practices that rethink what a given business monetizes. It is worth considering the difference between GEOINT-as-a-service and the data, tools, software, or platform-as-a-service. Traditionally, intelligence has been the product of using data, tradecraft, tools, and sensemaking to develop new insights that inform future actions. Innovations toward software-as-a-service and platform-as-a-service change the delivery mode of data and tools. GaaS includes the use of data, tradecraft, tools, and sensemaking to arrive at insights that inform action. A simple example of a GEOINT-as-a-service question is: "How do I get to point X?" The answer could be a complete transit route sent to a user's smartphone and automatically read to the driver without the end user having to worry about data, algorithms, processing, or even touching his or her device—simply put, GaaS provides a geospatial answer to a question. The user simply doesn't care about the process—yet the answer provider must make accuracy a hallmark of his or her business else they will not be able to gain and maintain market share. As a result, sometimes-disconnected processing and quality controls must not only be maintained at current levels, but also continuously improved. Consumer tolerance for inaccurate data is low. Nobody cares how great an app is functionally if it delivers the wrong answer as a result of poor underlying data.

The future geospatial workforce, wherever they work, will need different sets of skills. The growth in satellite, fixed-wing, and unmanned aerial system (UAS) platforms will provide persistent, multi-layered views of the earth on a daily basis and potentially generate new analytics from MS, HSI and SAR data sets. Geospatial analysis will be based on the lineage of events, observations, and actions. Analysts will need the ability to rapidly incorporate the use of and make sense of data from new sensors and collectors. This requirement will place huge demands on academia to remain agile in its educational offerings and stay abreast of emerging areas to provide graduating students the best competitive edge. Because it will be impossible to train analysts on every type of new source, education designed to develop critical thinking and sensemaking skills will be increasingly important.

GEOINT services pioneered by commerce stand in stark contrast to those using a governmental model. Traditional government GEOINT rests on a geospatial "large data" set that is well structured, rich in metadata, massive in size, and requires huge computational resources near the source of the data. Commercial GaaS relies on big data, which includes a much wider and less well-documented set of available data and relies primarily on cloud computing. Both commercial and government GaaS require innovation in mathematic and scientific methods for geospatial analysis. GaaS needs efficient algorithms to power and automate the next generation of big data analytics. It requires new approaches to ensure the veracity of the spatiotemporal component of all data.

The changing GEOINT world means we must create new relationships between government, industry, and academia. These new relationships will require a re-think of fundamental questions that underscore all aspects of the existing GEOINT business to include mission and national security needs, new commercial applications, evolving analytic methods and tradecraft, emerging data trends, and social responsibility. In partnership, each can help the others leverage the tremendous emerging commercial capabilities, and more importantly shift their organizational cultures to best take advantage of the growing power of geospatial information accelerated by GEOINT-as-a-service. ■

Anticipating The Consequences: Expanding the Discussion of Collaborative Intelligence

With all the crowdsourced, independent, and social media information flowing in real time, what are the consequences for the GEOINT Community, how will they happen, and when? Consequences from the perspective of an intelligence analyst may equate to or be a measure of success for an action taken as a result of timely, relevant intelligence. Consequence is also measured in the quality of the experience of the analyst or decision-maker (customer) as they engage in their normal duties using the tools and processes provided by a service provider, such as the National Geospatial-Intelligence Agency (NGA).

A consequence is more than a function of the latency between an adversarial event and chain reaction of responses. It is a function of an often overly informed (or over-stimulated) preconception of an outcome. That is to say, too much a priori inconclusive information about something restricts anticipated alternatives and can lead to an unintended consequence. A pervading preconception can lead an analyst to align data in order to anticipate what we already know—even while logically valid, this may not be sound. In the abundance of information and increasing complexity of problems, preconceived consequences have become impediments to good decisions; spatiotemporal reasoning models are overburdened with data and variables; and the urge to order and index everything is removing degrees of freedom from the analyst's ability to anticipate. Alternative or paradigmatic approaches are necessary to broaden analyst collaboration, leverage prevailing analyst sentiment, and draw on sheer luck, or what imagery analysts might call "fortuitous collection—or intelligence."

Are there ways to connect, combine, coordinate, corroborate, and collaborate the sentiments and reasoning power of analysts with the highly dynamic state of data (services, products, applications) resulting from continual and ubiquitous harvesting of closed and open sources? Consequences are not just the end-state of analysis; they are also the indicators of what's next.

Abundance of Data and Sources

In addition to Intelligence Community source methods, the velocity, volume, variety, and variability of information harvested from social media, commercial imagery, and other open sources exceed manageability. Socio-culturally harvested and aggregated information often include place names and other event-based attributes that challenge methods and tools historically geared more for spatiotemporally structured data. Evolving instrumentation and a burgeoning number of sensors (e.g. SmallSats) will continue to collect, discover, ingest, index, and store greater volumes of diverse data in shorter amounts of time, creating an illusion of ubiquitous and persistent awareness. Even if we could infer high veracity and validity of correctness of these enormous data sources, how does one monitor and reason the many cues and conditions for consequences? The potential of "unknown unknowns" led NGA to consider the impact of "fleeting signatures." In addition to a culture with the proclivity to order everything into preconceived models there are not enough collaborators coupled with too many unpredictable events for analysts and decision-makers to sift and manage.

Worldwide, socio-cultural, economic, and political behaviors continue to change both technologically and philosophically, impeding the thorough capability to model and predict events. Motivations and strategies of both neutral and adversarial actors are more complex as they adapt counter measures to responses (and consequences) that we cannot surmise. The cues for when, where, and why a "now-event" happens are clouded and nearly impossible to prioritize. Consequently, so are the requirements to collect against those cues. Still, data collection proceeds at unprecedented rates for multiple reasons—few of which are focused, integrated, corroborated, or deliberated, and the primary being a stated desire to "collect everything now and sort it out later."

The open-source intelligence enterprise includes unofficial communities of interest ranging from news aggregators and columnists, to conspiracy theorists, bloggers, academics, and arm chair analysts—each conducting his or her own collection and analysis and sharing on the web and via social media. Either unwittingly or driven by nefarious intent, the objectives of subversive elements are being carried out (and exposed) online. Tremendous amounts of ancillary data can be gleaned from social media. While often unconfirmed and under-structured, the data still offers significant breadth, depth, and variety to intelligence databases. Within social media and the greater corpus of open source, intelligence analysts are looking for cues that drive process and allow the anticipation or prediction of optimum circumstances for events, identify clues that support "forensic" decomposition of past events, and glean indicators that signify friendly and enemy vulnerability.

One ponders what 9/11 looked like before it happened—it could be said it was like Sept. 10 and every other day. Perhaps an analyst somewhere had an odd feeling before everything went down. A conspiracy theorist was busy blogging about vulnerability in the homeland. Facebook friends (if Facebook were around then) would have been curious over odd things being said by their foreign friends taking jet simulator flight lessons in the U.S. These are key clues lost in the morass of information, obscured in the periphery of more immediate analyst focus.

Over the past decade, the Intelligence Community has added to its arsenal many sensors and modalities, collecting droves of information from many places during a variety of events; all being analyzed with a deluge of technology, by people with varying experience. What have not changed are many disconnected analysts with understandably myopic views and the capacity to take in and understand so much implicitly interconnected information. And the enemy is even more complex and motivated than ever, but no matter how cautious, leaving many cues we are unfortunately unable to crowdsource or mine from afar. It's as if adversaries don't worry about what they publish, taking advantage of most analysts' inability to process such velocities and volumes of information.

Applications are evolving to collect, ingest, index, structure, store, assemble, and monitor data for currency and veracity. But the results of these applications do not always account for the possibility and probability of multiple consequences.

Is "Probably-Will-Happen" Enough of a Consequence?

In his book, "The Black Swan," Nicholas Taleb describes a metaphor for an "event that comes as a surprise, has a major effect, and is often inappropriately rationalized after the fact with the benefit of hindsight." A black swan is theoretically unpredictable and the confidence levels behind intelligence gathering leads to conclusions that are at best only "probably right." Taleb goes on to describe stochastic "tinkering" for detecting or identifying patterns or useful discoveries within complex and random data. In our terms, the morass of accessible intelligence requires us to tinker and step outside the rigidity of preconceived conclusions and think twice, or not at all, before "over-structuring disorder" as a prerequisite for deriving conclusions or at least preparing for unintended outcomes. Consequence can be complex, and a well-founded consequence may be an impetus to explore a chain reaction of consequences.

Were the November 2015 Paris attacks a black swan event? Could they have been anticipated? Were the build up of sentiments and sequence of cues detectable, and if so, was the sequence of events identifiable as a concern? There were many events, objects, and conditions that, when assembled correctly, might have provided the anticipatory cues—but this didn't happen. The presupposition (or preconception of an event) that might have led to reasoning toward such consequences was not prevalent—characteristic of the *unknown unknowns*.

Commenting on the theory of Ockham's razor, where the simplest solution often is the best solution, Sir Isaac Newton stated, "We are to admit no more causes of natural things than such as are both true and sufficient to explain their appearances." But the cautionary note is that an analyst may only search for and discover those cues that he or she knows leads to a known and already predictable event. Said by one NGA portfolio lead: "We keep validating the same things over and over." In fact, the sentiment of the analyst may be to assign probability to those cues simply based on their individual and limited knowledge of recent history. But not all events are predictable to a point that one can dissect them into associated cues and then search for or even recognize them. Furthermore, there is a difference between a cue's phenomena and its significance. An analyst might understand the nature of a signature more than its significance to a consequential event. Simply said, when you're only a hammer, everything looks like a nail.

"Probably [or even possibly] will happen" is enough of a potential consequence to change how we approach problems. In a world that strives to know everything going on everywhere right in the present, we must turn our focus on what's next. With a budgetary reduction of the cadre of analysts, there is an increasing need to innovate and automate techniques to anticipate persistently and assess the impact of gaps in content and time.

Collaborative Intelligence

Collaborative intelligence increases effective probabilities of knowing what's next and is facilitated by technology or interagency and organizational practice (or culture). But collaboration is not always convenient or possible. What if there were ways to effectively "automate" collaboration even between unwitting collaborators? Essentially, their behaviors with respect to content and services can be virtualized within collaborative ecosystems. Before we describe this, let's examine some of the basics.

Collaboration often implies the engagement between analysts, collectors, or data producers. However, collaboration crosscuts organizational domains and functional roles within those domains—for example, between data/information analysts (e.g., geospatial and imagery analysts) and subject matter experts (e.g., regional social psychologists who apply their trained and empirical knowledge and situational awareness (in operational, mission, cultural, political, social environments).

A collaborative approach in the above regard is a multi-analyst/multi-disciplinary approach versus one analyst/all source. In fact, it puts a technical or phenomenological understanding of source data on par with subject matter expertise. The inhibitors for collaboration between these groups include security clearances, network access, inability to collaborate, or a sheer lack of mutual awareness. More importantly, collaboration may be impeded by a failure to see any real connection between collaborators; and indeed, immediate consequences may be unrelated. But missing those unforeseen, unintended, or even small consequences can have significant downstream impacts.

One recently implied approach is to leverage a community of "uber-analysts" who, via a services model, provide voluntary (or commissioned) intelligence. This community of uber-analysts comprises a "virtualized intelligence organization" (VIO). Assuming some level of prerequisite professional qualification, this offers new ways to collaborate and capture awareness of events and crises as they evolve from as early on as the anticipatory phases. These VIOs would comprise the best, most relevant combinations of analysts, sensors, and subject matter experts, who are able to log into common work environments across all security and organizational domains (including unclassified). This remains a particularly important part of customer engagement between the major combatant commands and NGA.

This also relates to the emerging ideas of crowdsourced or volunteered geographic intelligence or information (VGI) provided by brokerages that offer intelligence as a service via commercial (unclassified) analytic environments, sources, tools, and analysts. With the increasing number of commercial data sources, many armchair analysts may emerge. This opens up an entirely new area that will be the focus of a different discussion.

Collaboration is not simply a characteristic of working together to share and discuss information. Automated means can match and merge metadata to search for logical connections and submit these to models or user-assisted tools. But less likely matched, disconnected sources can also be automatically "tinkered with" to uncover "serendipitous" discovery of spatiotemporal and attribute-oriented cues. These cues indicate an abnormality in continual patterns of life or behavior. These would be patterns otherwise deemed random (given rigid search criteria) that would go unnoticed. But these outlier consequences can be thought of as enticing intelligence that would drive new predictive analytic processes (to include open-source harvesting, alerts, or additional collaboration cues) for anticipating other uncertain and unintended consequences.

The serendipitous discovery and training on unmodeled patterns are monitored constantly by advanced computing technology, which will collect and store information at alarmingly increased rates. As new patterns come and go, unsupervised classifiers begin to accumulate experience with respect to the frequency and nature of these changes. Alerts provide cues that could arouse nonspecific analyst sentiment. Storing everything as events with time, space, and dynamic attributes (behaviors) can augment immersive awareness.

Serendipity: Accidental Cues "Left of Now"

In nature, what are seemingly random and disconnected events often have some inherent order to their attributes. Yet as human beings, we have the ability to instinctually operate amidst uncertainty. One might consider an analogous condition of uncertainty given the morass of data and cues available to intelligence analysts. Traditional collection and analysis techniques will remain valid insofar as a limited community of well-trained professionals is able to maintain an operational tempo for collection and analysis under relatively normal adversarial patterns and environments. However, with big data and the interconnectedness of compounded global issues, there is an increasing concern we are missing more than we are gaining in the volumes of data. Developing methods for "tinkering" can lead to serendipitous intelligence that provide cues for unintended or unforeseen consequences.

Activity-based intelligence, in its many definitions and components, and link analysis (as a form of tinkering) is popularly used to understand and map social topologies among nefarious networks based on their contextual and random actions, historical profiles, and associations. Many tools have been developed to understand linked human socio-cultural behavior. But, what if we applied link-oriented "tinkering tools" to our own analyst community or network, particularly with regard to how each analyst behaves in the execution of duties for mission objectives, their rationale, and the specific selection or assignment of spatiotemporal data they collect, process, or even discard? What if there was a way to derive cues, tips, etc. from the associations of activity via the secondary artifacts of the analyst tradecraft? We could use persona-based information such as their analytic habits, communications, sources, methods, and sentiment to empirically create a virtual collaborative workforce from which serendipitous intelligence can be derived through automated and semi-automated environments.

We foresee a need to employ link analysis to identify search and reasoning patterns (tools and workflows) between analyst personas and patterns among the data they collect and produce. In turn, these provide (alert patterns) for which other analysts might be looking. For example, two analysts from different regions or different areas of expertise, collect and analyze two entirely different events or objects within their own context, but when combined provide serendipitous patterns. These can then be matched against other experience databases, user personas, and sensors to pose an entirely different cueing context that triggers the objectives of a third GEOINT analyst.

Similarly, intelligence indicators can be derived by correlating the work of multiple analysts pursuing different key intelligence questions as they begin to explore identical ancillary questions, areas, data, suspects, objects, etc.

The need for collaboration also arises as a result of evolving knowledge sets and hence, evolving analyst processes. While the mission evolves, the analyst requires new information and is tapped to do a more evolved form of analytics—collecting from multiple data modalities, analyzing with broader arrays of reasoning power, disseminating at all stages of awareness, and having to apply real-time forensics of historical (or "now") events in order to anticipate and predict what's next.

In the aforementioned example, embedded tools within the analyst's workbench will record individual workflow, analytic strategies and tactics, common applications and data sources, and patterns in order to build analyst profiles, personas, and even avatars. When analysts sign on with their public key infrastructure signatures their recorded personas will help them quickly navigate through services and wittingly or unwittingly connect with others; too often search is directed at data rather than people who have information.

Conclusion

Our experience with causal events and potential outcomes is beginning to lag as many factors change faster than we can detect and therefore faster than we can adapt related intelligence business processes. The likelihood of an unanticipated event increases based on new, trending, socio-economic, and political dispositions in response to: overpopulation; climate change; water, food, and fuel shortages; and environmental degradation. The "unknown unknowns" require us to reconsider how we assess the value of all interconnected information and analysts (as human sensors); this is especially important as cyber vulnerability mounts and the IP address becomes the new geospatial coordinate.

The underlying technology for the Internet of Things will evolve quickly to handle and connect more situational and environmentally aware people and their smart devices—from phones, to vehicles, to home monitoring systems. Even before the Ebola outbreak in West Africa, we are able to amass broadly accessible information to assess the spatiotemporal impacts of travel, population control, and humanitarian relief and relocation as a result of disease, natural disasters, and epidemiology. Imagine this generating a "watch cue" with a focus on infectious disease as a form of bioterrorism—a cue that triggers an anticipatory response.

Collaborative intelligence, human factors, data calculus, and the appropriate factoring of intelligence uncertainty (be it with information provenance or analytical result) are key to anticipating consequences. It is an uncertain world overrun by uncertain data, driving uncertain complex reactions to these conditions. The knowledge and modeling of human reasoning behavior precedes technology proliferation. The analyst mission space changes frequently and new attitudes about roles in the interagency Intelligence Community will continue to evolve under political and economic pressure. GEOINT as a functional management area is evolving from a collection and production role to one of a persistent reasoning framework that embodies data, services, products, and applications provided by many agencies, sources, and domains—from highly classified to open source to global webscapes; from government analysts to the volunteer armchair analyst. Therefore, there's a growing need for subject matter expertise and professional certification. Better technology leverages analyst sentiment and massive amounts of information, and coalesces and crowdsources the expertise of a collaborative community the moment a cue occurs. The stakes of consequence are growing rapidly. "What's next?" in the future state of GEOINT is the new "now." ■

From the Q4 2015 Issue of *trajectory,* by Keith J. Masback, CEO, USGIF

The GEOINT Revolution

Multiple technologies are advancing and converging to unleash the power of geospatial intelligence

Five years ago the United States Geospatial Intelligence Foundation (USGIF) and some of our members helped fund an innovative media project called "The Geospatial Revolution." The video series, by Pennsylvania State University's public broadcasting affiliate, chronicled how a number of elements were coinciding to create a revolution in geospatial technology and information.

Today, we're experiencing a similar convergence of technology swirling around this thing we call geospatial intelligence (GEOINT), a term coined by the U.S. government just 12 years ago. GEOINT—not to be confused with simply "geospatial"—is loosely defined as the derivation of information from imagery, geospatial data in all forms, and analytics. As the government defined and began shaping its approach to GEOINT, remote sensing and geospatial information were transforming in commercial areas even faster and with greater implications. Over the past 12 years, the concept of GEOINT expanded beyond the national security sector to play a critical role in the arena of business intelligence. GEOINT-like capabilities enabled location-based services and have transformed myriad areas, including logistics, marketing, agriculture, and data analytics. GEOINT is increasingly recognized as a key differentiator offering a competitive advantage in both the B2B and B2C worlds.

Just as GEOINT has crossed into sectors beyond government and national security, it has also traversed international boundaries. The concept first took hold among the Commonwealth nations, but now GEOINT is a globally accepted phenomenon.

Because of this rapid growth, GEOINT professionals are in high demand. Simply put, if you are analyzing imagery, drawing information from it, and applying geospatial context to solve a problem, you are a "GEOINTer." Earlier this year, more than 21,000 people from 181 countries signed up for the first free massive open online course dedicated to GEOINT led by Penn State—proof the power of GEOINT is spreading around the globe.

The community is at an inflection point, embarked upon a GEOINT Revolution. Revolutions happen when a number of things come together serendipitously to create something new. Merriam-Webster defines revolution as "a sudden, radical, or complete change," such as "a fundamental change in the way of thinking about or visualizing something: a change of paradigm" or "a changeover in use or preference especially in technology."

While it is unclear where this revolution is headed, the GEOINT Community must immediately work to discern the end state of this transition and prepare to operate in the new paradigm. The GEOINT Revolution will change the way humans interact with where we are, what we're doing, and how we understand and characterize activity on Earth.

Each of the following technological components are arguably undergoing smaller revolutions in their own right, and together they create the synergy that is the larger GEOINT Revolution.

1. Precision Location Data

Most of us carry advanced geolocation devices in our pockets. They are nearly ubiquitous and have changed the way we view and interact with location. No one walked into the Verizon or AT&T store and asked for a mobile phone with integral GPS capability. It's there by law for enhanced 911. By the close of 2015 there will be more than 7 billion mobile cellular subscriptions worldwide—up from 738 million subscriptions in 2000—amounting to a penetration rate of 97 percent. Each one of those devices will have built-in geolocation capabilities. Precision location vastly expands and enriches the potential for applications to collect, aggregate, and make use of high-density information about a single locale and perform time-series analysis of data collected over time. The U.S. isn't the sole provider of precision location data. The rest of the world, with access to GLONASS, GALILEO, GAGAN, and BeiDou, is making tremendous advancements and adding precise data points with various sensors and systems.

Precision location data extends beyond our mobile devices. For instance, vehicles increasingly monitor their driver's location, ATMs record transaction locations and history, Internet browsers and search engines build geo-located history of an individual's online activities, etc.

2. Remotely Sensed Information

The hyper-availability of remotely sensed information—whether from platforms on the ground, in the air, or in space including electro-optical, radar, thermal, or multi- or hyper-spectral—was unimaginable just a handful of years ago. For instance, space-based, high-resolution imaging that was only available to select governments is now available to anyone with a checkbook. Commercial imagery provider DigitalGlobe can now sell images at 30-centimeter resolution and is moving toward 25 centimeters.

Meanwhile, SmallSat start-ups are changing the game with regard to how we approach remote sensing from space. Though high-resolution commercial satellites cost hundreds of millions of dollars to build, one of Planet Labs' Dove satellites can be produced for $60,000. Launch for a large satellite aboard an Atlas V rocket costs $10,000 per pound, but a ride on a reusable launch vehicle costs as little as $10 per pound. The next few years will be exciting as the optimal mix of larger, more capable satellites and smaller, less expensive satellites emerges.

Today, hobbyists, agriculturalists, disaster relief personnel, and many others are proliferating unmanned aerial vehicle (UAV) technology for imaging in their domains. In August, the Federal Aviation Administration made a significant step toward the commercialization of UAVs, approving more than 1,000 applications from companies seeking to operate the systems in U.S. national airspace. The agency predicts there will be more than 30,000 UAVs operating in national airspace by 2020. We are at the precipice of understanding how these vehicles will be deployed and employed.

The GEOINT Revolution is fueled by this next generation of remote sensing, which has made it much more accessible to create robust new sensing networks.

3. Software

Incredibly capable geographic information systems and increasingly powerful software for imagery exploitation and data analytics continue to flourish. Without this elegant software, GEOINT data simply wouldn't be as accessible, retrievable, and user-friendly. Large companies such as Esri and Hexagon have invested heavily—in close and continuous contact with their massive respective user bases—to create capable software that has unlocked much potential from geospatial information.

Another aspect of the ongoing GEOINT Revolution is the growing adoption of open-source software. GEOINTers of all stripes are increasingly familiar with and able to write or use scripts as part of their creative processes. A search of "geospatial" on GitHub turns up nearly 800 repositories and more than half a million code results. Traditional software engineer roles undoubtedly remain, but analysts whose second language is Python or another program to create "mashups" of information in a geospatial context now perform some of the work. The GEOINT Revolution will continue to transform how we think about and approach software development, integration, and adaptation.

4. Broadband Communications

The spread of broadband communications infrastructure via fiber optics enables the rapid transfer of very large files, while the ordinariness of routers, switches, and increasing bandwidth in space allows broadband to be spread around the world in ways never anticipated. According to the United Nations Broadband Commission, more than 130 countries now have national broadband or information communication plans. As of December 2014, mobile broadband penetration had reached more than 81 percent, and fixed-line broadband subscriptions tallied 358 million according to the Organisation for Economic Co-operation and Development.

5. Processing Power

Processing power was once a primary limiting factor to combing through large imagery and geospatial files. According to The Economist, it may be only a decade before Moore's Law—the concept of shrinking transistors to double the amount that can fit on a microchip approximately every two years—hits a plateau. In the meantime the smartphones in our pockets have the same processing power of the massive Cray-2 supercomputer built only 30 years ago, and we're still moving forward. Decoding the human genome, which originally took 10 years, can now be accomplished inside of a week. Imagine the potential over the next decade, especially with regard to GEOINT-related data and information, as high-power computing becomes more widely available. Human processing remains important as well. Large-scale crowdsourcing efforts, made possible by platforms such as Tomnod, leverage the power of volunteers to train an unprecedented number of human eyes on imagery. Crowdsourced crisis mapping continues to be instrumental to the success of humanitarian relief efforts such as stemming the Ebola outbreak in West Africa or responding to the earthquakes in Nepal.

6. Storage

Storage limitations have been greatly minimized by the vast adoption of online server networks. The emergence of the cloud as a distributed way to manage how data and information are stored, processed, and delivered presents a seemingly endless set of options to approach a task. Should you process in situ or in the cloud? How much of your data should you store in the cloud versus on your device?

It took 26 years to develop a 1 GB hard drive but only four years—between 2007 and 2011—for hard drives to quadruple in storage from 1 to 4 TB. A 128 GB flash drive can now be purchased for less than $30, and some predict 20 TB hard drives will be commonplace in the near future.

The rise of the cloud can be largely attributed to the lowering cost of storage. As recently as 1990 it cost $10,000 to store 1 GB of data in the cloud. Today, anyone with an Internet connection has access to 15 GB of free storage via Google Drive and the ability to store 1 TB of video on Dropbox for $100 a year.

This increase in local and cloud storage provides infinite possibilities of combinations if you are a developer or analyst looking to solve a problem.

7. Data Analytics

Big Data was initially viewed as a problem, a "data tsunami" that would overwhelm users. The GEOINT Community realized this onslaught of data could be incredibly useful if the proper tools were in place to derive information from it. The emergence of data analytics has made volume, even huge volume, an advantage and a differentiator. Ninety percent of the world's data was created in the last two years alone. Half a million tweets full of open-source intelligence are generated each day. Dynamic data analytics is required to make use of this information. Data analytics, and now predictive analytics, are bringing about change in many fields, including health care, telecommunications, utilities, banking, and insurance. The GEOINT tradecraft both benefits from and contributes to the leapfrogging advances in data analytics.

8. Mobile

The growing mobile device market, from smartphones to activity trackers and other wearables, is creating a rapidly proliferating sensor web. Nearly half a billion mobile devices and connections were added in 2014, when mobile data traffic equaled 30 times that of the entire Internet in the year 2000. By 2019, mobile data traffic is expected to increase tenfold.

Video uploads from smartphones have added to the boom in open-source intelligence. One hundred hours of video is uploaded to YouTube each minute, and Facebook video views have increased fourfold in the last year to about 4 billion per day.

Building on the ubiquity of mobile devices and precision geo-location information, imaginative ways to leverage location are among the hottest areas of mobile app development. Enabled by mobile devices, location-based intelligence and services are changing the game in terms of consumer marketing, business intelligence, and academic research. Nearly 75 percent of smartphone owners use location-based services. We use location-based apps daily to locate friends, find restaurants and entertainment venues, check public transportation schedules, request ride services, and even to find our way around a building and receive offers from retailers based on our location (see pg. 32). More than $10 billion was spent on U.S. mobile advertising in 2014, with $3.5 billion spent on location-based mobile advertising alone—a number representative of GEOINT's permeation of business intelligence.

9. Virtual & Augmented Reality

Virtual and augmented reality are entering into everyday tasks in fields ranging from medicine to vehicle maintenance, urban planning, and more. GEOINT data is essential to accurately model real locations in gaming, virtual reality, and augmented reality environments.

It is estimated that by 2018 the virtual reality market will grow more than 200 percent and acquire 25 million users. Analysts predict the augmented reality market will grow to $5.2 billion in 2016, and that by 2017, more than 2.5 billion augmented reality apps will be downloaded to mobile devices.

10. The Internet of Things

Not only are humans becoming sensors via our smartphones and wearable devices, but so are our possessions. The Internet of Things will provide a tremendous live-streaming set of data about our environment. It will facilitate an unprecedented understanding of where we are, what we do, and how we engage with one another and the items that surround us. Imagine your phone telling your garage door, thermostat, and television you've arrived home. Without lifting a finger your garage door is open, the AC is on, and the 6 o'clock news is queued up. The number of devices connected to the Internet already far exceeds the number of people on Earth, and conservative estimates project there will be 50 billion connected devices globally by 2020. Some experts posit the number of connected devices could actually reach as high as 250 or 300 billion by that time.

Opportunity and Responsibility

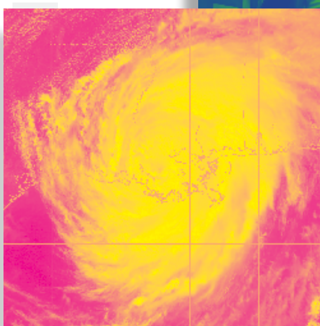
Throw these 10 elements in a pot, stir gently, put it on simmer, and you have the recipe for the GEOINT Revolution. And it's already happening.

It's imperative the GEOINT Community start thinking and talking about the GEOINT Revolution today, in the most expansive context possible, so we can shape its direction rather than be dragged along behind it. The revolution demands we explore challenges differently, such as thinking more broadly about GEOINT and remaining open-minded regarding new business methods. The Intelligence Community created and nurtured the idea of GEOINT over the past decade or so, but as GEOINT expands rapidly into almost every sector of the economy we will learn from others who are approaching the discipline with fresh sets of eyes, ideas, and motivations. We must not hold on stubbornly to the GEOINT that was, but rather embrace the GEOINT that is to be.

There's a tremendous opportunity at hand for the GEOINT Community, and along with that opportunity comes significant responsibility. It's incumbent on all who identify as GEOINTers to take some time to determine the role he or she will play in the GEOINT Revolution, and then to step up. Rapid change is underway, and although we don't quite know yet what the outcome will be, USGIF will remain at the forefront of fostering discussions regarding the impact of each of the revolutionary elements described above.

Indeed, the recognition of the capabilities inherent in these new technologies is very exciting, and new processes will be developed, but ultimately it's people that must have the tools to take advantage of all that technology has to offer. It is our duty to educate, train, and professionally develop the workforce of today, and of the future, to harness the technologies integral to the GEOINT Revolution. The people who are driving the revolution are an entirely different generation than those who launched it.

Consider the implications of the GEOINT Revolution, and appreciate that if we don't enable professionals in all industries to understand how GEOINT affects their particular field, and if we don't learn from them reciprocally, we won't be prepared to operate effectively in a profoundly changed world. ■



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